

North Carolina Agricultural Research Service

PLAN OF WORK

2002 Annual Report of Accomplishments and Results

North Carolina Agricultural Research Service
College of Agricultural and Life Sciences
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Introduction and Certification

North Carolina State University is North Carolina's 1862 land-grant university and the only Research I land-grant institution in the state. The North Carolina Agricultural Research Service (NCARS) within the College of Agriculture and Life Sciences serves not only as the college's agricultural, environmental and biological sciences research arm but also provides the research foundation in these areas for educational activities within academics and extension. NCARS is the principal state agency for research in agriculture, life sciences and forestry. Its research projects involve North Carolina State University's colleges of Agriculture and Life Sciences, Forest Resources, Physical and Mathematical Sciences, Engineering, and Veterinary Medicine and the School of Human Environmental Sciences at the University of North Carolina-Greensboro. Within the college, NCARS coordinates research in 18 departments and works in partnership with the North Carolina Cooperative Extension Service and Academic Programs.

The mission of NCARS is to develop the knowledge and technology needed to:

- ❑ improve the productivity, profitability and sustainability of industries in agriculture and life sciences;
- ❑ conserve and improve the state's natural resources and environment; and
- ❑ improve the health, well-being and quality of life of all citizens of North Carolina.

In FY 2002, NCARS personnel include 265 tenured and tenure-track research faculty accounting for approximately 185 full-time scientist equivalents, most on shared appointments with academics or extension. Working with these faculty members are over 366 research professors, researchers, research assistants and graduate students; 438 laboratory and field technicians and 176 clerical staff. These faculty members and support personnel conduct basic and applied research in 609 projects to support more than 70 commodities as well as many related agribusinesses and life science industries.

The following Plan of Work Annual Report highlights accomplishments and impacts of research conducted through the North Carolina Agricultural Research Service and emphasizes the high priority areas in agriculture and life sciences for North Carolina now and in the near future.

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I. Planned Programs

National Goal 1: An Agricultural System that is Highly Competitive in the Global Economy

Program Area 1: Technologically Integrated and Sustainable Crop and Livestock Production Systems

Subprogram Area 1a: Crop Production Systems

Overview

Research activities in this program area have concentrated on developing improved pre- and post-harvest handling techniques and production management systems for field, fruit and vegetable crops and on improving the acceptability and quality of these crops. In addition, research has focused on improved production management systems for ornamental and floricultural crops, turfgrass and landscape plants to enhance rural and urban environments. Some highlights of accomplishments in this program area are listed below.

- Two native grasses, switchgrass and gamagrass, were shown to provide forage of high nutritive value during the summer stress period, resulting in animal gains of 1.7 to 2.2 pounds per day. Both of these grasses are very flexible in management systems. Both switchgrass and gamagrass can be preserved as direct chop silage or when wilted without a preservative if care is taken to exclude oxygen.
- Studies in tobacco to alter grade distribution across stalk positions showed that cured-leaf color was the primary factor in tobacco receiving a tip grade. These studies also indicated that priming grades could be eliminated without reducing yield by removing the six bottom leaves.
- Skinning of sweetpotatoes can be reduced at harvest by flail mowing vines or applying Ethrel 7 to 14 days in advance of harvest.
- Versions of the Herbicide Application Decision Support system were customized for each of 10 Southern states.
- Research showed that shading does not significantly interact with herbicide action in Roundup Ready cotton.
- Yields of maturity group II soybeans were up to 20% higher at 36/26 C temperatures than at 32/22 C temperatures, indicating different responses than observed for genotypes in later maturity groups.
- Investigations found that crop and agronomic weed species are highly sensitive to aluminum toxicity. This helps explain their confinement to limed, agronomic soils in the Southeast. Successful invasive species, e.g. kudzu, are more tolerant to aluminum.
- Large amounts of aluminum can accumulate in mycorrhizal structures and block aluminum from entering root meristematic areas. Research suggests that compounds may be exuded from roots of some species that bind to aluminum in the rhizosphere, preventing aluminum entry into roots of sensitive plants. This observation may explain why hardwood species can follow pine in succession even though hardwood species are sensitive to aluminum.
- Studies of weed seed survival in adverse environments indicate that nitrogen is important for these plants to be competitive. These observations are providing a conceptual model for nitrogen management in sandy, low-fertility soils, where a degree of weed control could be achieved through careful nitrogen management.
- Studies of weed seed dispersal indicated that small seeds are transported relatively long distances on the soil surface during the growing season by wind and/or water.
- Weed-sensing sprayers were found to detect weeds accurately in the row middle, and real-time, site-specific herbicide application reduced herbicide active ingredient and costs by 50-85% in corn, cotton and soybeans. The sprayer is applicable to both conventional and reduced tillage systems.
- Subsurface irrigation in peanut resulted in similar yields and less disease as compared to overhead sprinkler irrigation.
- Studies with peanut indicated that planting a single cultivar in a field, versus mixtures or strip plots, is the most effective strategy to increase yields. Further, even though peanut fixes nitrogen, addition of nitrogen may improve yields.

- Tomato spotted wilt virus infection in peanut was compared in different planting arrangements and in twin row planting patterns did not differ from narrow row planting patterns.
- Skikimic acid accumulation, when sampled seven days after treatment, is an effective diagnostic tool and predictor of yield and economic loss resulting from glyphosate drift to non-transgenic crops, including cotton, peanut and tobacco.
- Experimental herbicides were tested in Hoelon-resistant ryegrass in wheat, and a new sulfonylurea herbicide gave consistent control.
- Research indicated that in spite of lower cotton fiber quality, transgenic herbicide-resistant and insect-resistant cottons returned greater net profits and substantially reduced pesticide use. Similar results were found for maize.
- Yield maps can be developed based on use of GPS technology in tobacco; however, variable nitrogen showed no advantage over traditional uniform application rates.
- Microbiotic compost was shown to reduce soil borne diseases and nematodes; the use of this compost is a possible alternative to methyl bromide fumigation.
- Chemical thinning for the popular Fuji apple variety has been developed, allowing this variety to become more feasible to manage under North Carolina growing conditions.
- Research identified chemical alternatives for methyl bromide fumigation for strawberry production. Alternatives included metam sodium, Telone II, Telone C-35 and chloropicrin.
- The germination requirements for seabeach amarnath are being studied in an attempt to provide information for the greenhouse production of seedling transplants for dune stabilization projects.
- Experiments with dark aid-cured tobacco production and curing produced cured leaf with outstanding physical properties, although nitrosamine levels were unacceptably high. The studies concluded that lower temperatures during curing and decreased drying capacity provide an excellent environment for the conversion of nitrate to nitrite prior to the nitrosation of secondary alkaloids into nitrosamines.
- A new protocol was developed for the recover of RuBisCO from tobacco leaf tissue. This protocol allows recovery of the protein without heating the homogenate. This will greatly facilitate the purification of transgenic proteins.
- A procedure was developed in which compounds such as diterpenoids can be recovered from the surfaces of tobacco leaves by solvent washes. This work identified several inexpensive solvents that can be used in the recovery of valuable leaf-surface compounds.

IMPACTS

Managing Nitrogen in Corn

a. The low price for corn has increased the need for growers to use cost effective systems. In addition, there is a growing concern over nitrogen contamination of surface and groundwater. Proper fertilizer management practices such as application timing, rate and nitrogen source are required to maintain yield while reducing costs and environmental contamination. Researchers developed a new management system for application of nitrogen to corn. This system is based on multiple applications of small amounts of nitrogen. Actual nitrogen rates applied at each stage of corn development are determined by soil or plant tests that rely on remote sensing. Nitrogen management systems have been tested in several locations across North Carolina, with a key systems test located at Kinston, North Carolina. These tests found that: 1) corn growers should apply at least half the nitrogen required by the crop at planting to obtain optimum yields, 2) new soil tests for mineralizable nitrogen have the potential to predict how much nitrogen to apply at planting, 3) the remaining nitrogen can be applied as late as stage VT without reducing corn yield, 4) remote sensing of corn color using an infrared photograph of the field can accurately predict how much nitrogen to apply at VT, 5) a model for predicting corn nitrogen fertilizer requirements was successful when used on farmer fields, and 6) nitrogen management systems using both an early and late application based on soil tests and photographs of the field at VT reduced the amount of nitrogen required to grow corn and reduced nitrates in groundwater. Growers using this system can decrease nitrogen requirements by 5 to 10% while actually increasing yield, particularly in years with drought stress. Extension meetings and field day demonstrations were used to show and describe the system to corn growers.

b. Impact: Growers readily adopted the recommendations. Surveys at summer field days showed that over 60% of the growers were applying at least half of the nitrogen required by the crop at planting. Based on field comparisons at the Kinston test site and from grower reports, this practice helped increase corn yield by 20 to 25 bushels per acre despite drought conditions. Many growers found that their yields actually increased over those recorded in 2001, when weather conditions were ideal for corn. If we conservatively calculate that only a tenth of the state's corn acres realized a yield increase from this practice, this amounts to an increase of 120,000 bushels of corn grown in North Carolina. At \$2 per bushel, the financial gain to the state economy was \$480,000.

c. Source of Funds: North Carolina Corn Growers Association, USDA-IFAFS Grant, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Growing Disease-free Blackberries

a. Production of cultivated blackberries in the Southern U.S. is limited, but interest in this high-income specialty crop is growing as consumers demand a local supply of these highly desirable fresh fruits. However, as acreage of this crop has grown, there has been an increase in the number of plants with virus-like symptoms. Concomitantly, a decline in berry and yield quality in cultivated blackberry genotypes has been observed by researchers and growers in blackberry plantings in North Carolina, South Carolina, Arkansas, Virginia and Mississippi. In some cases severe symptoms and plant decline were observed in plantings two to four years after establishment. Researchers identified four viruses (Tobacco ringspot virus (TRSV), Tomato ringspot virus (ToRSV), Raspberry bushy dwarf virus (RBDV) and Impatiens necrotic spot virus (INSV)) by serological assay (ELISA) in commercial fields or at research stations in North Carolina, South Carolina and Virginia. One, or more likely a combination of these viruses, is suspected to be a major contributor to the decline in established commercial plantings. Of particular concern is the virus INSV, which has not been found in blackberry previously. It is related to a virus currently devastating tomato, potato, tobacco and other crops in the region. Working with the NC State University Micropropagation Unit (MPU), a graduate student produced meristem-tip culture in vitro plants of several patented blackberry genotypes (Apache, Arapaho, Kiowa, Choctaw, Chickasaw, and Navaho) from the University of Arkansas breeding program. These plants are being virus-indexed by grafting and ELISA and will be ready for planting in field trials in the spring of 2003. In cooperation with NCCIA, Blackberry Certification Standards are being developed and should be in place to take effect in early 2003. This will help us to establish a nursery industry in North Carolina. Researchers are working with one grower to develop a protocol for propagation of clean plants.

b. Impact: The steps taken thus far should enable North Carolina to become the leading supplier of clean blackberry nursery stock and help to ensure the health of future blackberry plantings.

c. Source of Funds: Alfred P. Sloan Foundation, NC State University Provost matching funds, North Carolina Specialty Crops Program, Southern Region Small Fruit Consortium, Hatch formula funding, state appropriations

d. Scope of Impact: Regional

Supporting Medicinal Herb Growers

a. There is tremendous interest among growers in the Southeast in medicinal herb production. In the mid-1990s there was little reliable information available on how to produce or market medicinal herbs. Trials on a wide variety of herbs at several mountain research stations provided the information growers needed to start production. These studies were also valuable as demonstrations for extension agents and botanical product buyers and resulted in several buyers looking to North Carolina for herbs. By 1998 there were dozens of medicinal herb growers producing under contract in North Carolina. At that time, the North Carolina herb industry was estimated to have grown to a value of \$27 million. Unpredictably in 1999 the medicinal herb market went soft throughout North America, and no one could sell their herbs. It took several years for the industry to stabilize. In 2002, the market was slowly expanding, and growers are again contacting their county agents about growing medicinal herbs. In response, new studies were initiated on sun-requiring herbs in the upper piedmont on and woodland botanicals in the mountains. A project was also initiated to evaluate the market for North Carolina herbs and to develop a more secure marketing plan for North Carolina growers. To provide support and networking opportunities for this industry, the North Carolina Natural Products Association was initiated in 2002. The association is a good example of a diverse group of individuals from a variety of backgrounds coming together with a common vision. The initial directors of this association include representatives from NC State

University, the North Carolina Arboretum, the North Carolina Department of Agriculture and Consumer Services, Yellow Creek Botanical Institute, The Biltmore Company and four medicinal herb companies. The North Carolina Summit on Natural Medicinal Products was held to promote the growth of the North Carolina medicinal herb industry by bringing together representatives from agriculture, medicine and the natural products industry.

b. Impact: More growers throughout North Carolina are planting medicinal herbs. Working with the Smoky Mountain Native Plant Association, researchers at NC State University have helped 13 growers in Graham County, North Carolina start commercial medicinal herb plantings. Returns from a recent survey indicate that there are a large number of growers interested in growing medicinal herbs, and at least 300 acres of herbs are in production.

c. Source of Funds: Golden LEAF, Hatch formula funding, state appropriations

d. Scope of Impact: North Carolina

Assessing a Threat to Wine Grapes

a. Interest in wine grape and wine production continues to increase in North Carolina. In recent years, the number of wineries has grown from 13 to 26, while the value of wine grapes in the state is expected to increase from \$2.5 million in 2001 to \$4.5 million in 2003. Most of the increase occurred as a result of the establishment of *V. vinifera* and French-American hybrid grapes in the Piedmont and mountains. However, expansion of the industry in the Piedmont is threatened by Pierce's disease, which is caused by the bacterium *Xylella fastidiosa*. Pierce's disease, which is lethal to grapevines, is considered to be the principal factor limiting production of *V. vinifera*/French American hybrids and *V. labrusca* in the Southeast. The bacterium is transmitted by insect vectors from many common annual and perennial plants. Research at NC State University has focused on better defining those areas in North Carolina where Pierce's disease is likely to be a problem and identifying some of the most important reservoir hosts. Pierce's disease was identified in grapevines in 18 of 22 vineyards in the Piedmont. Disease incidence ranged from a few scattered vines to nearly 100%. In the most severely affected block, the incidence of seriously affected vines increased from 24% in 2001 to 54% in 2002. The Pierce's disease bacterium was detected in 20 wild hosts, including wild grape, blackberry, wild rose, cherry, oak, sycamore, Virginia creeper, sweetgum, sumac and Bermuda grass. Researchers are examining historical temperature data from 36 weather stations in North Carolina and Southern Virginia and, based on a survey, have determined that the risk of Pierce's disease is lowest in regions which have 5-6 days with temperatures < -9.4C or 12-14 days <12.2 C.

b. Impact: These studies have further defined the area in North Carolina where the risk of Pierce's disease is greatest. They have already had an influence on planting decisions of farmers and others who were considering planting grapes in regions of North Carolina where the risk of Pierce's disease is high. Because of the high cost of establishing a vineyard (~\$10,000/acre) it is important that growers select sites where the likelihood of losses to Pierce's disease is not great.

c. Source of Funds: Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Making Apple Growers More Competitive

a. Technology developed at NC State University is allowing North Carolina apple growers to store apples for a significantly longer time while maintaining quality. This allows growers to sell to smaller, higher value niche markets for an extended period with high-quality fruit. MCP, or 1- Methylcyclopropene, was developed at NC State University in the early 1990s and patented by the university in 1996. MCP binds to horticultural crops at sites where ethylene, a ripening agent, normally binds. This makes the crops insensitive to ethylene. Apples treated with MCP maintain their firmness, crunch and acidity much longer after harvest and even after being held at room temperature. In 1999 the patent rights were sold for MCP use on horticultural crops. In 2002 the company that developed MCP for commercial use received a commercial label from the Environmental Protection Agency for use of a product called SmartFresh on edible crops. The EPA approved the label for SmartFresh on apples under a new biopesticide program because of the very low toxicity of the product and the fact that treated fruit have no detectable residue. Educational programs on SmartFresh use were developed and presented to growers at both the state and county level. In addition, the mass media (radio, newspapers and TV) were used to educate the public on how this new technology will benefit the consumer.

b. Impact: SmartFresh has increased the market window for North Carolina apples. One grower who was involved in an on-farm demonstration treated Ginger Gold apples, an early season variety, with SmartFresh. The grower was able to hold his fruit for three weeks longer than other growers. The treated fruit sold for a premium at an Apple Festival, because the grower was the only one there with high-quality Ginger Gold apples. If not for SmartFresh, this fruit would have been disposed of prior to the Festival at significantly lower prices. This technology will also allow growers to target other high value markets, such as gift packs and high-end retailers, with fruit that will maintain firmness and flavor under less than ideal marketing channels.

c. Source of Funds: North Carolina Apple Growers, Hatch formula funds, state appropriations

d. Scope of Impact: National

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$582,786	\$5,511,206.30	\$1,360,385.84	\$851,641.01	23.689	40.6	62.337	29.372

Subprogram Area 1b: Animal Production Systems

Overview

Research was conducted to improve animal productive efficiency in an environmentally sustainable manner by investigating basic physiological processes of animals; studying relationships among grazing animals, forages and the environment; determining the efficiency and profitability of animal production systems; and examining the impact of animal production systems on animal products used by humans and on consumer acceptance of animal products. Some highlights of accomplishments in this program follow.

- A study of how endocrine regulation of growth may be altered in health-challenged swine suggests that endocrine regulation of growth via the insulin-like growth factor system is not affected in health-challenged swine.
- A study comparing fat and carbohydrate energy sources in manufactured diet for young pigs showed that pigs fed either energy source grew at similar rates. In addition, a study examined the source (triglycerides vs. phospholipids) of long-chain fatty acids that are important in the development of neural tissue.
- Studies were conducted to evaluate the influence of turkey sires and dams on the decrease in fertility and embryonic survival rates that occur in turkey breeding lines. These studies indicate that declines in survival rates associated with selection for growth have basis in the strain of the dam and the type of egg produced. These studies also indicate that different environmental conditions need to be provided when incubating eggs from lines of turkeys selected for increased body weight. The incubation period may need to be altered to better match the embryonic growth potential of poults. Studies are underway to determine optimal incubator conditions to match growth.
- Studies with mice demonstrated that the use of probiotics does not increase energy utilization of the intestinal tissues, thereby increasing the maintenance requirements of the animal.
- The 34th North Carolina Layer Management and Performance Test was hatched and placed in August, 2001. Several research projects on molting behavior of egg-type hens were conducted in conjunction with the test.
- Faculty participated in the 2002 National Egg Quality School, attended by 62 students from 20 states, one U.S. territory and Belgium.
- Research on the conversion of animal mortalities into value-added feed ingredients resulted in a new product that has been approved by the American Feed Control Officials for registration as hydrolyzed whole swine (whole poultry) protein. Depending on how environmental regulations and animal by-product feeding laws are written in the future, this technology has the potential to save the North Carolina swine and poultry industries over \$5 million in mortality handling and disposal costs.
- Appropriate enzyme applications to poultry feed were demonstrated to reduce the emissions of phosphorus, nitrogen, and other minerals by improving diet digestibility by up to 5%. Dietary supplementation of novel enzymes, oligosaccharides and betaine was found to stabilize gut microflora, discourage enteric pathogen colonization, and improve enteric health. And a new technology called in ovo feeding was invented to improve early enteric development of poultry and improve resistance to enteric disease.

- A study comparing several alternative litter sources indicated that chopped Bermuda hay can be used as litter for turkeys, especially during the brooding period, when relatively little litter caking occurs. In Eastern North Carolina, hog lagoon effluent is sprayed on Bermuda hay fields to utilize hog manure nutrients, but more hay is being produced than can be used.
- Studies were initiated to link the mechanisms governing skeletal muscle growth to the diet fed an animal. Work focused on the calpain/calpastatin system. Presently, cDNA probes have been generated for the three calpain sub-units and calpastatin, and the effect of nutrition on calpain levels has been examined during the early post-hatch period. Furthermore, the effect of nutritional status in the early post-hatch chick on GAPDH mRNA has been investigated. The effect of nutritional level and refeeding on the satellite cell population has been examined in the early post-hatch period. Apoptosis has been determined to be a mechanism that can adversely affect muscle size when feed is withheld early post-hatch. It has also been demonstrated that the plane of nutrition early in life, through its effects on satellite cells, influences ultimate muscle size. It has also been shown that myonuclear apoptosis is an important mechanism governing ultimate muscle size when feed is withheld from an animal.
- A transgenic chicken line carrying the -galactosidase gene was produced, providing an important model for developmental biology research.
- Gonadal primordial germ cells (PGCs) were shown to be capable of remigrating to the gonad of a different avian species, and thus can be used to construct interspecific germline chimeras. This feature of gonadal PGCs will promote their use in the production of interspecific germline chimeras and may assist in developing strategies for the production of transgenic poultry.
- Studies are underway to define effective methods to manipulate primordial germ cells (PGCs) for altering sex ratios in birds. This should open the door for the development of procedures that will allow the manipulation of sex ratios in birds through the transfer of germ cells from one egg to another.
- Studies determined the anatomical and physiological basis of the circadian system in quail. This information provides a mechanistic explanation of such rhythmic functions as ovulation and timing of oviposition as well as how a bird distinguishes between short and long day lengths with appropriate reproductive responses.
- Studies indicate that using organic forms of minerals and reducing the level of supplemental dietary minerals in swine diets reduces minerals excreted in swine waste by 30 to 40% without sacrificing gain and feed efficiency in growing animals or reproductive performance in breeding animals.
- Leptin secretion was examined in prepubertal heifers given vehicle or bovine somatotropin. Somatotropin treatment decreased serum leptin concentrations without affecting age at puberty. Another study examined genes affected by leptin treatment.
- Research aimed at reducing the excretion of ammonia, odors, phosphorus, zinc and copper in swine waste through dietary modification using fiber as a key ingredient was conducted. In addition, an investigation of the recovery of minerals from animal waste indicated that the bioavailability of the minerals is at least as high as in the original feed when the minerals are refeed to animals. This suggests this type of recycling could significantly reduce the importation of minerals into the state, thus potentially reducing the load of excreted minerals to the environment.
- A study of esophageal ulcers in swine indicated that buffers in pigs' water supply have the potential to decrease stomach damage during feed withdrawal or enhance repair following refeeding.
- Feeding and digestibility studies with goats and cattle showed that harvested and dried duckweed has high nitrogen and phosphorus content, is acceptable as a feedstuff, and can serve as a convenient way to recycle nitrogen and phosphorus, thereby reducing the negative impact of those nutrients on ecosystems.
- Work continues to determine the technical, operational and economic feasibility as well as environmental impact of 18 waste treatment technologies considered promising alternatives to existing swine waste management practices.
- In an effort to better understand Large Offspring Syndrome, which can occur in offspring from bovine embryos produced in the laboratory using in vitro fertilization technologies, the expression of genes that control normal fetal growth was altered in fetuses from embryos produced in the lab.
- Reducing phosphorus excretion by using phytase in sow diets is being investigated in cooperation with four other states. In addition, reducing the environmental impact of swine production by removing fiber fractions from corn through processing (dehulled, degermed corn) is being studied. Initial work indicates this technology can greatly reduce nutrient excretion in swine.

- A study showed that the effect of ionophore and unsaturated plant oils fed to dairy cattle is additive for all trans fatty acids except for trans-10 C18:1. In the case of trans-10 C18:1, ionophore and oil interacted to give higher trans-10 C18:1 concentrations in ruminal contents than would be expected simply by adding their individual effects. These results suggest that antimicrobials and plant oils fed together in dairy rations can depress milk fat percentage more severely than either additive alone, particularly in diets high in rapidly-fermentable starch sources, such as barley.
- Infrared technology was tested as a means of quickly assessing the quality of eggs, feedstuffs and complete feeds.

IMPACTS

Better Diets for Cattle

a. Copper deficiency has been a major problem in beef cattle in much of the United States. In the past, copper has been supplemented to beef cattle primarily in the form of copper oxide; however, research at NC State University showed that the copper in copper oxide is in a form that cannot be used by cattle. A study showed that copper supplementation in an available form increased calf weaning weights by 17 pounds per calf.

b. Impact: Because of this research, almost all beef cattle mineral supplements have been switched from copper oxide to forms of copper that cattle can absorb. Assuming that 25% of the beef cows in North Carolina graze forages that are copper deficient, and a 75% calf crop, this change has resulted in approximately a \$1 billion increase in income from calf sales alone. For the entire U. S., this would mean a \$73 billion increase in income from calf sales. This does not include any improvement in animal health that may have resulted.

c. Source of Funds: industry, Hatch formula funds, state appropriations

d. Scope of Impact: National

Developing Aquaculture

a. Aquaculture has been shown to be a viable alternative agricultural enterprise in parts of North Carolina where water supplies are abundant. But what about parts of the state where water supplies are limited? Since 1989, NC State University researchers have been working to develop technology for intensive fish production indoors with limited water supplies. The North Carolina Fish Barn program combines water treatment components from around the world to allow for production of freshwater and marine fin-fish in tanks with very little water usage.

b. Impact: The Fish Barn program assisted Southern Farm Tilapia in designing and establishing a hatchery, nursery, and two tilapia production facilities. Production capacity of these facilities is three quarters of a million pounds per year. In addition, Southern Farm Tilapia has developed a 15,000 square foot processing and refrigerated storage facility. The Fish Barn program assisted Deca J Farms with diversification of an existing swine production business into aquaculture. Deca J Farms has built a state-of-the-art hatchery, nursery and Phase I growout facility for the production of yellow perch. When Phase II is completed in 2004, the facility will have the capacity to produce over a million yellow perch annually. Additionally, the Fish Barn program is supporting, with onsite technical assistance, seven other tilapia production fish barns in North Carolina. These facilities are under production contracts with Southern States Cooperative of Richmond, Va. These contracted tilapia facilities have the capacity to produce nearly 1.5 million pounds of fresh fish annually.

c. Source of Funds: private sector, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Better Poultry Diets

a. On-going research has shown that all supplemental phosphorus may be removed from the laying diets of broiler breeders if the breeders are grown on normal diets and a source of phytase is used in the laying diet. However, broiler breeders on these low-phosphorus diets exhibit some wet litter problems that contribute to bacterial growth and ammonia volatilization (an air quality issue), increased contamination of fertile hatching eggs, increased contamination of broiler chicks, disease and dermatitis on the feet and skin. Some evidence of similar problems in broilers has also been observed, along with skeletal, pulmonary and cardiovascular problems. Preliminary investigations suggest that judicious use of dietary sources of potassium and chlorine can restore the electrolyte balance of the body in such a way as to ameliorate the wet litter and health concerns associated with low-phosphorus diets.

b. Impact: The North Carolina poultry industry manages over 9 million broiler breeders that produce fertile hatching eggs. These hatching eggs supply over 20% of all the broilers (*i.e.* almost 2 billion) grown in the U.S. annually. This nutritional change to overcome the wet litter problems associated with low-phosphorus diets could lead to the

removal of over 1.25 million pounds of pure phosphorus from broiler breeder diets in North Carolina alone. Nationally, this change could remove over 6 million pounds of excreted phosphorus. This formulation change will assist in improving the sustainability of the industry while at the same time reducing chick production costs.

c. **Source of Funds:** industry, Hatch formula funds, state appropriations

d. **Scope of Impact:** International

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$701,108.91	\$4,442,548.91	\$6,298,886.96	\$821,513.68	12.555	32.09	60.3	12.71

Subprogram Area 1c: Biological Systems

Overview

Research was conducted to map, identify and analyze genes responsible for quantitative traits; characterize the structure and expression of genes and pathways required for growth, development and behavior; develop new approaches for gene transfer and gene regulation, and new methods for visualizing gene products within cells; identify biochemical factors and pathways involved in response to abiotic and biotic stresses and environmental factors such as drought, gravity, light and pathogens; and elucidate the structure, function and evolution of macromolecules that are key to growth, development, defense and behavior. Following are some highlights of accomplishments in this program.

- A single *Drosophila* quantitative trait loci (QTL) affecting variation in avoidance response to benzaldehyde was mapped, and the gene identified. The novel gene, *Vanaso*, contains a putative guanylate binding protein domain, is highly polymorphic, and is expressed exclusively in the third antennal segment. The step-wise gene discovery strategy employed allows characterization of effects of recessive lethal genes on adult phenotypes and enabled identification of a gene that contributes to sex-specific quantitative variation in olfactory behavior.
- Transgenic flies were used to establish an experimental paradigm for the discovery of genes that might be involved in the development of glaucoma.
- The nature of genetic variation for *Drosophila* longevity, starvation resistance, olfactory, locomotor and mating behavior, and sensory bristle number in a population of recombinant inbred lines was investigated by estimating quantitative genetic parameters and mapping quantitative trait loci (QTL). QTL for each of these traits have been identified and candidate loci are being narrowed down.
- Quantitative trait locus (QTL) mapping was used to identify genes that control important life history traits in *Arabidopsis*, particularly in field ecology settings.
- The largest comprehensive DNA sequence variation dataset for *Drosophila* was generated, consisting of approximately 8 Mb of sequence covering 40 kb in 200 strains.
- Statistical methodology for a “multi-trait association mapping” approach to associating molecular genetic and phenotypic variation was developed. This technique has applications in complex trait mapping, human genetics and evolutionary biology.
- A Mixed Model Analysis of microarray data statistical approach to quantification of microarray gene expression data was introduced, with a wide range of applications in agriculture, medicine and basic biological research.
- A rapid assay for the expression of the key female-determining gene in southern flounder was developed, which is anticipated to speed the characterization of culture effects on sex ratio and allow assessment of the contribution of different habitats to producing female flounder in the wild by allowing determination of the sex of developing individuals before this can be determined through microscopic inspection of the gonads.
- The low linolenic acid trait mediated by the *fan* locus in soybean was shown to be caused by the reduced expression of a specific FAD3 gene (encoding a linoleic acid desaturase). This information may be exploited to help develop specific molecular markers for this trait.

- Nicotine demethylase is responsible for the production of the secondary alkaloid nornicotine, the precursor of a particularly potent carcinogen. In an effort to clone the demethylase gene, a DNA chip containing nearly 5,000 cDNAs represented in the EST database was generated. This chip was hybridized to fluorescently labeled RNAs from isogenic Converter (high nornicotine producers) and Nonconverter (low nornicotine producers) tobacco plants. Several candidate genes have been identified and are being subjected to further investigation.
- Turkey breeder hen fertility declines as hens are selected for rapid growth, and the causes for the declines are unknown. The hypothesis was proposed that pathological polyspermy might be responsible for very early embryonic deaths. To test the hypothesis, sperm binding to the outer perivitelline membranes of eggs was measured. Both sire and dam effects of two lines exhibiting different binding affinities were investigated. The binding showed sire, dam and interaction effects determining not only the number of fertilized eggs but the early embryonic mortality as well. Thus, embryonic mortality in turkeys may be affected by the binding ability of spermatozoa and ova.
- The naturally occurring tomato mutants *dumpy* and *curl-3* were shown to be brassinosteroid-deficient and insensitive, respectively. Several brassinosteroid-regulated genes in the bean have been cloned. In a study of the brassinosteroid receptor in *Arabidopsis*, the receptor was shown to contain an active kinase domain, and a substrate recognition sequence was identified. The BR receptor was shown to phosphorylate an important regulatory protein in *Arabidopsis* involved in the overall control of plant growth and development and in the initiation of protein synthesis.
- The earliest way plants detect changes in the gravity vector may be through the displacement of amyloplasts and statoliths. Using newly developed methods, the movements of amyloplasts and statoliths in *Chara* rhizoid cells and in Maize pulvinal bundle sheath cells were analyzed with a large degree of accuracy. Long-term dynamic studies of statolith movement show a complex interaction between the statolith and cytoskeletal elements.
- Two mapping populations were created from public inbred maize lines that are potential sources for resistance to fumonisin accumulation and *Fusarium* ear and kernel rot. These populations are being used to evaluate whether some quantitative trait loci (QTLs) for ear rot resistance also confer resistance to fumonisin accumulation, and whether QTLs are consistent across populations and environments.
- Analyses of the role of mannitol and its catabolic enzyme mannitol dehydrogenase in plant-pathogen interactions indicate that mannitol dehydrogenase represents a new class of pathogen resistance gene that has exciting potential for introducing increased fungal resistance in plants.
- A plasma membrane lipid mediated signaling event in tobacco cells grown in suspension culture and in *Arabidopsis* plants has been identified and genetically altered. Biochemical analysis of the cells indicated that the expression of inositol polyphosphate 5-phosphatase increased the flux through the phosphoinositide signaling pathway. In addition, plants expressing the transgene exhibit a reduced gravitropic response.
- A DNA chip containing nearly 5,000 soybean cDNAs was generated and is being used in microarray expression hybridizations with RNAs isolated from soybean cell cultures and leaf materials exposed to agents inducing an ER stress response. Analysis of this complex data set is in progress and ultimately should help identify the genes involved in regulating the production and assembly of the storage oil and protein.
- An increase in intracellular calcium was shown to be necessary for the activation of neocortical cytosolic phospholipase A(2) (cPLA₂) during tumor necrosis factor (TNF)-induced apoptosis, and calcium was found to be necessary for intracellular translocation. In apoptotic cells, cPLA₂ was found to translocate to the nucleus, a process that was blocked by verapamil. Calcium was also shown to be an important second messenger for the activation of cPLA₂ in a variety of apoptotic responses.
- A study on the factors controlling the expression of a behaviorally important neuropeptide hormone, arginine vasotocin, in bluehead wrasses demonstrated that the vasotocin gene is influenced primarily by social interactions in bluehead wrasses. In other vertebrates, this gene is primarily under the control of gonadal hormones. This finding highlights the value of this model system for exploring mechanisms by which social interactions influence neural function and behavior. The distribution of the receptor for this neurotransmitter was mapped in the brain of bluehead wrasses, and a key neurotrophic factor (BDNF) was cloned.
- In studies on the molecular systematics of the *Diptera* and their close relatives, gene fragments were amplified and sequenced for multiple species of *Therevidae* and their closest relatives. 28S rDNA, opsin, and elongation

factor 1a were chosen as candidates for sequence comparison. Nucleotide sequences were obtained by automated DNA sequencing. Phylogenetic analyses were conducted for these data and compared to the morphological hypotheses of relationship.

- A study on the evolution of different genes in *Arabidopsis thaliana* was completed, providing information on how development evolves.

IMPACTS

Aiding Aquaculture

a. Aquaculture is the most rapidly expanding type of livestock farming in the United States, and hybrid striped bass (HSB) farming is among the fastest growing forms of finfish aquaculture. Previously, all hybrid striped bass were produced from wild broodfish caught during their spawning migrations. This dependency on wild fish creates numerous problems for fish farmers and precludes selective breeding. If hybrid striped bass farming is ever to reach a level of development comparable to the broiler chicken industry, it will be necessary to fully domesticate the parental lines, genetically improve the fish to produce a superior fish and discover breeding techniques that allow them to be reproduced on demand. NC State University researchers developed the largest and most diverse striped bass and white bass broodstocks in the country and domesticated white bass over five generations and striped bass over three generations. Scientists showed, for the first time, that domesticated fish can be used to produce hybrid striped bass with fecundity, fertility and yields of fry and fingerlings at commercial scale and rates equivalent to those obtained using fully mature, wild broodfish captured on their spawning grounds. This work opened the door to selective breeding of hybrid striped bass, which is now well underway. As a consequence of this effort, the top seven producers of hybrid striped bass in the U.S. have joined with NC State University to genetically improve hybrid striped bass for commercial fish farming.

b. **Impact:** Domestication of the fish, as we have accomplished for both striped and white bass over several generations, opens the door to selective breeding and production of genetically improved hybrid striped bass for growout. Superior performing fish are needed because the hybrid striped bass industry faces severe competition from foreign producers of similar white-fleshed fish, either wild-caught or farmed. Improved efficiency of production, via genetic improvements to the fish, will ensure continued competitiveness of hybrid striped bass farming in the U.S. Currently, because they are relatively expensive to produce, hybrid striped bass are sold mainly to high-end restaurants or sold live into lucrative Asian ethnic markets. These markets are limited, creating competition among growers and driving prices and profits down. Hybrid striped bass sales need to expand into the general retail market, which will only be possible if production efficiency can increase, allowing prices to drop while maintaining profit margins. Development of an improved fish through selective breeding is key to realizing this goal.

c. **Source of Funds:** North Carolina Sea Grant Program, USDA, UNC Office of the President, Hatch formula funds, state appropriations

d. **Scope of Impact:** National

Breeding Better Peanuts

a. Peanuts are a high value crop, but they also require large amounts of inputs to control insects and diseases. As a result, large amounts of fungicides, nematicides and other pest control measures are applied to the plant and soil during the growing season. Plant breeding efforts with the cultivated peanut have been hindered because only moderate to low levels of resistance to many disease and insect problems are found in the cultivated gene pool. However, many wild peanut species are highly resistant to the most devastating disease and insect problems of peanut. A genetics project to utilize wild peanut species for crop improvement has produced 15 germplasm releases with high levels of disease and insect resistance. Nine of these lines have significantly higher levels of *Cercospora arachidicola* (early leafspot) resistance than is found in the cultivated germplasm collection. Very high levels of Sclerotinia blight resistance also have been identified in two of the leafspot-resistant lines. Other lines released are resistant to root-knot nematodes, southern corn rootworm and several other insect pests. Attempts are now being made to improve yield and quality in these lines. To aid selection, wild and cultivated species are being analyzed with DNA markers so introgression can be followed from diploid to tetraploids and to associate molecular markers with components of disease resistances. To date, linkages between molecular markers and genes conditioning root-knot nematode resistance, southern corn rootworm, leafhopper and several components of early leafspot resistance have been identified.

b. Impact: After yield is increased to acceptable levels in the two leafspot lines with high levels of Sclerotinia blight, the use of foliar and soil-applied fungicides will be significantly reduced and possibly eliminated. Levels of resistance are more than adequate to completely eliminate use of nematocides when the backcrossing program into North Carolina cultivars is completed. Suppression of southern corn rootworm and other insects will similarly reduce chemical controls for these pests. When the improved germplasm lines are utilized under farming conditions, not only will the producer save significant amounts of money, but there will be fewer chemicals applied to the environment in an area of North Carolina that has sandy soils and high water tables.

c. Source of Funds: North Carolina Peanut Growers, National Peanut Foundation, Hatch formula funds, state appropriations

d. Scope of Impact: regional

A New Crop for North Carolina Farmers

a. With the decline in tobacco and other program crop acreage and general low prices for agronomic commodities, farmers are looking for new crops that can be produced and marketed successfully. Researchers at NC State University are working to develop an “industrial strength” hot pepper. This research has focused on developing cultural systems for and gathering seed of a pepper that is 35 times hotter than a Jalapeno. Such a pepper would not be eaten, but used for various industrial products such as pepper mace, insecticide, deer repellent and pest fumigant. NC State University faculty have evaluated varieties and cultural systems to improve efficiency of production and maximize yield, while an industrialist has developed methods to hold the pepper in a mash form until extractions can be done.

b. Impact: In 2002, eight North Carolina growers produced 16 acres of peppers. Growers are expected to produce about 40 acres of peppers in 2003, with acreage expanding as more seed and processing capacity come on line.

c. Source of Funds: Golden LEAF, USDA/CSREES Small and Part-Time Farmer Program, Hatch formula funds, state appropriations

d. Scope of Impact: regional

Understanding Nitrogen Applications

a. There has been much public concern that nitrogen fertilizer applied to turfgrass is contributing to pollution of water supplies. Nitrogen can move through the soil and reach groundwater or run off soil and reach surface water, and excessive amounts of nitrogen can lead to algae blooms and fish kills and can be a human health hazard. Experiments at NC State University are evaluating the fate of nitrogen in managed turfgrass systems. At golf courses and sod farms throughout North Carolina, researchers are examining nitrogen use on warm and cool season grasses. Tissue, soil and water samples are being analyzed continuously to determine the extent of nitrogen loss to the environment. Shallow wells and lysimeters are being used to measure subsurface nitrogen movement. Other experiments in growth chambers are designed to provide information about specific mechanisms involved in nitrogen uptake and cycling, which control nitrogen use efficiency.

b. Impact: This research is providing the first scientifically based information on nitrogen utilization and losses in managed turfgrass systems. The results clearly indicate that, when best management practices are followed, little nitrogen is lost and there is no indication of contamination of water supplies. The research is raising the environmental awareness of the turfgrass industry and providing data that can be used by regulatory agencies to make informed decisions when establishing environmental guidelines and laws.

c. Source of Funds: Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$203,828.19	\$2,198,833.96	\$824,259.76	\$352,311.43	8.513	24.02	22.203	8.758

**Goal 1, Program Area 2:
Plant and Animal Germplasm, Genetic Resources and Conservation, and Plant Improvement**

**Subprogram Area 2a:
Crop Improvement**

Overview

Research activities in this program area concentrated on improving plant productivity and quality of fruits, vegetables and agronomic crops through breeding methodologies to increase yield and quality and reduce the incidence of diseases and insects; increasing biological efficiency through control of metabolic processes and gene regulation in plants used for food, fiber and fodder; and developing methods and strategies to produce more efficiently horticultural and agronomic crops in North Carolina. Some program accomplishment highlights are listed below.

- Burley tobacco hybrid NC 6 was released. This hybrid, which produces high yields and good black shank resistance, was introgressed from the species *Nicotiana plumbaginifolia*.
- Thirty-one new inbred maize lines were released.
- The first genes in soybean that condition drought responses were discovered.
- Soybean lines bred for drought tolerance yielded up to 25% more than conventional varieties under stress conditions.
- Introgression from exotic Asian cultivars into U.S. soybean cultivars produced new advanced breeding lines, which have consistently out-performed popular U.S. cultivars.
- The first DNA mapping population in soybean was released to the public. The population also has phenotypic data for nine traits.
- Three genome regions that increased grain yield in maize were identified.
- Several winter oat genotypes that are more freeze-tolerant than other genotypes were evaluated in the field and have potential for improving winter hardiness.
- Molecular analysis revealed that the tobacco mosaic virus resistance gene *N* has been transferred to multiple chromosomes of the *N. tabacum* genome from *N. glutinosa*.
- A gene conferring a high level of tolerance to necrotic isolates of PVY was transferred from *N. Africana* to *N. tabacum*.
- Transgenic plants from perennial ryegrass were identified
- Three gene promoters were cloned from rice using a genomic approach, and one showed activity similar to the most-used maize *ubi1* promoter.
- DNA sequence information was obtained for more than 10,000 cDNAs from a gene library developed from senescing leaves of a tobacco line that produces high quantities of normicotine.
- Floralina, a fusarium wilt race 3 resistant tomato hybrid, was developed in a cooperative breeding effort between N.C. State University and the University of Florida.
- Resistance to early and late blight is being incorporated into fresh market tomatoes to control these two devastating diseases, which occur worldwide.
- A new potato variety, Harley Blackwell, was released in cooperation with the USDA-ARS. This variety is similar in yield and quality to Atlantic, the dominant chipping variety in the U.S. but is less susceptible to internal heat necrosis, a major problem in the mid-Atlantic and Southeast U.S.
- A superior sweetpotato clone, NC98-608, has been identified. NC98-698 is equal in yield and quality to the major variety Beauregard but is superior in packout and is set for release in 2004 if extensive testing on a commercial scale is successful in 2003.
- Three new peach varieties, China Pearl, Intrepid and Challenger, have been released. All have good cold hardiness, ensuring growers of a crop even in years when cold temperatures injure standard commercial varieties.
- A genetic mapping project of sweetpotato is underway. The project is expected to yield molecular markers to speed up the breeding process for important traits, including shape, color, disease and pest reaction, and yield.

- Three new southern highbush blueberry varieties, Craven, Pamlico and Lenoir, all adapted to mechanical harvesting for the fresh market, will be released in early 2003
- A correlation was found between protein concentration and isoflavonoid content in soybean. Correlations also were found between the amount of nitrogen a soybean plant receives during growth and isoflavonoid content in seeds.
- The low linolenic acid trait in soybean mediated by the *fan* locus is likely to be caused by the reduced expression of a specific FAD3 gene, which encodes a linolenic acid desaturase.
- Studies indicated that linuron and fluometuron are transformed to metabolites within 24 hours by excised leaves of small tobacco seedlings in transgenically modified plants but not in wild-type plants.
- Research revealed that phosphorylation of serine-15, the major phosphorylation site on sucrose synthase, affects the conformation of the N-terminus of the protein but does not prevent the protein from binding to membranes. The finding is important because localization may influence how plant cells use sugars for different metabolic pathways.
- Serine-170 on sucrose synthase was established as a minor phosphorylation site in vivo, suggesting that phosphorylation of this site may be part of a mechanism that triggers the proteolytic degradation of the enzyme.
- Cloned genes that encode cytosolic pyruvate kinase in developing soybean seeds demonstrated that the enzyme can be modified by removal of a portion of the C-terminus to produce a slightly smaller version of the protein that accumulates during seed development. This modification produces a protein that is enzymatically active, but may have altered regulatory properties and may be exploited in the future to influence seed composition and increase crop value.
- The C-terminal tail of 14-3-3 omega was shown to be an autoinhibitor that plays a critical role in the activation by cations of the binding of the 14-3-3 proteins to their targets. This discovery may lead to new approaches for molecular genetic manipulation of these proteins, which interact broadly with cellular proteins, affecting enzymatic activities and possibly proteolytic degradation.
- Significant differences in freezing tolerance were observed in a population of recombinant inbred lines, which should impact the understanding of freezing tolerance in oats by associating freezing tolerance with other known traits in the oat genome.
- Fructan that was purified from rye plants, which are very winter hardy, contained a membrane stabilizing factor; but fructan from oat, which are not winter-hardy, did not contain the factor.
- Laboratory protocols were developed for quantitatively determining phytic acid in mature soybean seed. It then was determined that most species of phytic acid in soybean are in the form of hexaphosphate.
- The gelling mechanism of soy protein was investigated, and it was discovered that hydrogen bonds, hydrophobic interactions and disulfide bridges play roles in commercial soy isolate gelatin. Disulfide bridges or bonds are important in the initial gel network, although their presence is not essential for gel formation but adds rigidity to the gel network.
- The cultivar Prolina, a high-protein soybean, has higher cysteine content than other soybean cultivars.
- Methodology was developed to investigate root structures by magnetic resonance imaging, and soybean images with clear visualization of primary, basal and small lateral roots have been produced. This has significant implications for future studies of physiological processes in plants.
- Studies on absorption and translocation of water were evaluated, and correlations between root hydraulic conductance and the surface area of the stele were significant, explaining a large percentage of the variation among soybean genotypes. However, no single physical barrier to translocation is paramount in explaining genotypic variation.
- A germplasm conversion program to incorporate Latin American maize germplasm into North American lines resulted in families that performed at least as well as commercial checks.
- Studies showed that populations of Roundup Ready soybeans could go as low as 50,000 seeds per acre in full season without sacrificing yield, and as low as 100,000 seeds per acre in double crop production systems.
- Applications of the herbicide Roundup to Roundup Ready cotton need to be very precise to avoid problems with pollination and reproductive sterility, a study showed.

- Research showed that a new product, BASF 131, for the control of auxiliary bud growth in tobacco can be used with reduced rates of maleic hydrazide without loss of sucker control.
- Planting costs in cotton can be reduced by up to 44% without reducing yields when using skip-row or hill drop planting systems, studies showed.
- Research indicates that increasing seeding rates in corn will increase corn yield, but plants must be uniformly spaced in the field.

IMPACTS

Protecting Tobacco Transplants

a. Greenhouse production of tobacco transplants has replaced traditional plant bed production in recent years. Greenhouse production involves seeding tobacco into polystyrene trays filled with soilless medium. The trays are then floated on a shallow reservoir of nutrient solution. While this system is preferred for transplant production, the environmental conditions in greenhouses can be favorable for diseases. A common disease problem in greenhouse transplant production is *Rhizoctonia solani*. Greenhouse diseases can be destructive, and currently there are no effective chemicals registered for greenhouse use to control *Rhizoctonia*. With the increase in greenhouse transplant production and the lack of labeled fungicides to control seedling diseases, it is important to identify resistance to this disease. In an effort to identify resistance, a diverse array of about 100 tobacco accessions was inoculated with a stem rot and a target spot isolate of *Rhizoctonia*. Substantial statistically significant differences in overall infection rates were observed for the different lines. Several lines with low levels of infection were identified. Burley tobacco varieties had low infection rates for the target spot isolate, while the flue-cured lines were all highly susceptible. For the stem rot isolate, the line with the least infection was a cigar filler tobacco line from New Zealand. Only 4% of plants were infected. *Nicotiana rustica*, a relative of tobacco that previously had been reported to have some resistance to *Rhizoctonia*, had one of the lowest infection rates, with only 14% of plants infected.

b. Impact: The first step in breeding a tobacco cultivar with disease resistance to transplant diseases is to identify tobacco lines that contain resistance. This screen will provide the basis for future cultivar improvement and development. In addition, this work will provide a guide on the relative susceptibility of various popular cultivars to *Rhizoctonia*, which may influence a grower's cultivar choice. The potential impact of this work is the reduction of economic losses due to diseases in transplant production and reduced reliance on chemicals to prevent disease.

c. Source of Funds: N.C. Tobacco Research Commission, Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Fighting Gummy Stem Blight

a. Gummy stem blight, caused by a fungus that occurs naturally throughout the South, is a major disease of watermelon in North Carolina. Researchers at NC State University have been working to find resistance to gummy stem blight. Watermelons were collected in Africa, the Middle East and other parts of the world, especially east Asia. These watermelon collections (accessions) are stored at the Regional Plant Germplasm Station in Griffin, Georgia. Watermelon accessions were screened for resistance to gummy stem blight. Those that were most resistant were retested, and the most resistant progeny after self-pollination were selected. These selections are being used to determine the inheritance of resistance and to develop resistant varieties for use by North Carolina growers.

b. Impact: The four most resistant accessions have been released to interested researchers, seed companies and industry personnel, who are using them in breeding work designed to produce resistant cultivars.

c. Source of Funds: Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Combating Powdery Mildew

a. Powdery mildew causes approximately \$2 million in losses to North Carolina wheat producers annually. Although research by breeders has been very effective in combating this problem, the fungal population continually adapts to overcome resistance genes in new wheat varieties. Thus, we observed continued losses but at a fraction of the potential losses that would occur without current research efforts. New resistance genes are typically brought into production one gene at a time. Since 1996, NC State University plant breeders have released 11 wheat germplasms with powdery mildew resistance transferred from species related to common wheat. As a result, we are now in a position to combine, or pyramid, more than one new resistance gene into the next

generation of wheat varieties. In order to do this effectively, however, we must 1) determine the exact genetic control of the resistance in the wheat germplasms and 2) use DNA technology to fingerprint the resistance genes in order to combine more than one into a new variety. Five populations of 100-200 lines were developed using five different germplasms and a susceptible wheat variety as parents. These populations underwent field and greenhouse screening. The data generated indicated powdery mildew resistance was controlled by a single gene in each germplasm. DNA was extracted from each line in the five populations and subjected to AFLP analysis. To date, the resistance genes in two of the five germplasms have been tagged with markers.

b. Impact: The determination of the genetic control of powdery mildew resistance provides a blueprint for how breeders should use these resistance sources when developing new wheat varieties. More importantly, we now have the ability to stack more than a single resistance gene into new varieties through the use of DNA markers.

c. Source of Funds: North Carolina Small Grain Growers Association, Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$427,848.45	\$3,982,975.53	\$2,235,122.07	\$876,761.50	16.4	30.82	41.84	15.38

Subprogram Area 2b: Animal Improvement

Overview

Research was conducted to improve animal performance by investigating basic biological systems that modulate life processes, studying the genome of animals, and creating useful animal models for the study of human and animal diseases. The impact of this research will enhance our understanding of the basic genetic and biological basis of animals as well as improve the human condition via the study of animal models. Following are some accomplishments in this area.

- Windows QTL Cartographer version 2.0 was released. The major update is the addition of multiple interval mapping (MIM) procedures for one trait. MIM is a new generation of statistical method for mapping quantitative trait loci (QTL) by simultaneously searching and mapping multiple QTL.
- Transgenic pigs were developed that may be used as a model in research on retinitis pigmentosa in humans. Pigs were provided to a researcher at Queen's University in Belfast, Northern Ireland, who is studying retinitis pigmentosa.
- Work is underway to identify the basic mechanisms of controlling oocyte maturation in cattle by identifying the specific genes and gene products involved. Once these genes are identified, manipulation of the expression of genes controlling oocyte maturation will be used to speed, delay or even prevent the process of oocyte maturation. Manipulation of the process of oocyte (female gamete) maturation prior to IVF can be used to facilitate and/or improve the efficiency of clinical procedures for livestock embryo production. Manipulation of oocyte maturation may provide novel opportunities for the development of contraceptive interventions for non-livestock species, including exotic animals and humans.
- Polygenic obese M16 mice were compared with ICR controls for an array of protein and lipids. The next step will involve high throughput proteomic and metabolomic phenotyping in an M16 x ICR F₂ QTL mapping population. Combining these physiological and predispositional analyses will facilitate the placement of QTL effects within specific pathways and may differentiate between QTL with direct or regulatory influences on growth traits. The objective is to integrate QTL analysis with proteomic and metabolomic analysis to facilitate a better understanding of the genetic architecture of complex traits in mammals.
- Studies show significant declines in reproductive measures in both Holstein and Jersey herds in 10 Southeastern states over the past 25 years, and particularly in the past 15 years. These data imply that both genetic and environmental factors are involved. Because of this and other efforts, reproductive traits will be measured and considered in future USDA genetic evaluations of dairy bulls. Also, a new regional project has been established to examine methods of improving reproduction in dairy cattle, including both selection strategies and crossbreeding.

- Controlled and field evaluations of three commercial sire lines of swine were conducted. This project allowed pigs of each genetic line to express their full genetic potential as well as the genetic potential that is expressed in the commercial setting. Comparative data for maximum potential and expected potential were collected while controlling for as many management factors as possible. Across production environments, pigs with maximum genetic expression grew 30% faster and consumed 27% more feed on a daily basis, resulting in a 27% greater lean gain per day. A genetic line by environment interactions were observed for feed intake, lean efficiency and gain to feed ratio. Possible causes of these interactions include stocking density, pig to feeder space ratio, and pig to water ratio or environmental quality.
- Research focused on how genes specify development of the body during the process of embryogenesis through study of the genetic controls of development in the model system, *Drosophila melanogaster*.
- An experiment demonstrated that selection for increased swine litter size can be effective with appropriate management, i.e., reduction of number nursed to 10 or fewer at farrowing. The lines developed will provide extremely useful material for genomic studies.
- A series of research publications, professional development programs, and producer conferences provided information on pasture-based dairy production strategies that have the potential to compete economically with larger confinement dairy production systems in North Carolina and other areas where pasture production is feasible.

IMPACTS

Managing Heat Stress in Cattle

a. North Carolina dairy farmers suffer significant economic losses annually due to decreased reproductive performance during the hotter months of the year. Temperature and humidity index readings indicate lactating dairy cows may experience heat stress through more than half the year. Various cooling methods and feeding regimens have been identified to manage heat stress, but they are expensive and have had only limited success. A study used treatment with the hormone GnRH after insemination to attempt to improve pregnancy rates in dairy cows bred during heat stress periods.

b. **Impact:** Study results indicated an increase in pregnancy rate from 18% in controls to 35% in GnRH treated cows. The use of GnRH to increase pregnancy rates will reduce days open by approximately 40 days, resulting in an average saving of \$50 per cow.

c. **Source of Funds:** North Carolina Dairy Foundation, Hatch formula funding, state appropriations

d. **Scope of Impact:** regional

Developing Aquaculture with Flounder

a. Summer and southern flounder are important fisheries resources and promising aquaculture species in North Carolina. Wild stocks are threatened by overfishing, and stock enhancement is being considered. Both issues require detailed knowledge of the reproductive biology of these species and development of technologies to implement their successful culture in captivity. Research at NC State University has characterized the process and timing of sexual development, demonstrated profound temperature effects on sex determination and growth rate as well as validated techniques for producing all-female stocks for culture. Finally, researchers have developed a molecular marker for female sex determination and begun experiments exploring the influence of environmental factors on its expression.

b. **Impact:** Seafood consumption is rising rapidly in the U.S., but yields from capture fishing continue to decline. The summer flounder fishery was worth \$28 million on the Eastern seaboard in 1996 despite landings that were only 35% of those realized annually during the 1980s. Southern flounder is a promising aquaculture crop for the hard-water Castle Hayne aquifer of Eastern North Carolina due to their tolerance of low-salinity conditions.

Despite the current and potential economic importance of these two species, critical basic information was lacking on sexual development and the effects of environmental temperature on this process. From an aquaculture standpoint, effective technologies for creating monosex cultures of only the faster growing females (up to 300% heavier than males) were lacking. NC State University research has contributed critical new information for use by fishery managers, in hatchery operations that will be crucial to both stock enhancement and aquaculture, and for the development of a commercially viable flounder aquaculture industry.

- c. **Source of Funds:** North Carolina Sea Grant Program , National Marine Fisheries Service, Hatch formula funds, state appropriations
- d. **Scope of Impact:** regional

Measuring the Fertility of Dairy Bulls

- a. Researchers developed a method of accurately measuring the fertility of dairy bulls that accounted for environmental effects that had biased previously used procedures. Using this method, dairy farmers can determine the true inherent fertility of bulls.
- b. **Impact:** Dairy farmers now have available an accurate measure of the fertility of bull semen. Based on previous economic estimates, this more than doubles the potential profit from using artificial insemination bulls.
- c. **Source of Funds:** Dairy Herd Management Services, North Carolina Institutional Breeders Trust Fund, American Jersey Cattle Club, North Carolina Dairy Foundation, Hatch formula funds, state appropriations
- d. **Scope of Impact:** National

Understanding Complex Genetic Traits

- a. Complex, or quantitative, traits are affected by multiple interacting genes that are sensitive to the environment. Most characters that are important for human health (for example, susceptibility to heart disease, cancer or diabetes); agriculture (production and yield traits); and adaptation of populations to their environments are complex traits. A major challenge is to determine which genes affecting complex genotypes. The use of model genetic systems, such as the fruit fly, *Drosophila melanogaster*, enables quick and efficient testing of new methods of analysis. Three methods have been used to map genes affecting several complex traits in *Drosophila* (numbers of sensory bristles, olfactory behavior, mating behavior, starvation resistance and longevity) and to determine their properties. Transposable element insertional mutations with quantitative effects have been induced, and the affected genes cloned using the transposable element as a molecular tag. Quantitative trait loci have been mapped by linkage to molecular marker loci in pedigreed populations. Finally, associations between molecular variation in candidate genes and phenotypic variation for the trait have been examined in random mating populations.
- b. **Impact:** The complexities of quantitative variation in *Drosophila* impact the design of studies to determine genes affecting quantitative traits in humans and other organisms. It has been proposed that such genes can be mapped by genotyping a random sample of individuals for single nucleotide polymorphisms (SNPs) in protein coding regions of candidate genes and associating the genotype with disease or other trait status. The work with fruit flies has shown that this strategy is likely to fail unless (1) the density of SNP markers is much greater than has been proposed, (2) markers are included in non-protein coding (regulatory) regions, (3) larger sample sizes are used, and (4) the effect of sex and other demographic factors is included. A potential future impact of this research is the identification of genes conferring postponed senescence.
- c. **Source of Funds:** National Institutes of Health, National Science Foundation, W.M. Keck Center for Behavioral Biology, Hatch formula funds, state appropriations
- d. **Scope of Impact:** International

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$197,209.46	\$1,998,001.50	\$860,714.92	\$124,475.06	7.57	18.34	23.2	3.87

**Goal 1, Program Area 3:
 Plant Protection Strategies (forest, horticultural and field crops)**

Overview

Research activities in this program area concentrated on developing and enhancing pest, pathogen and weed management technology for growth and production of forests and horticultural plants for greater enjoyment and profitability in an environmentally sustainable manner; improving the understanding of ecology and genetics of pest, pathogen and weed populations and their interactions with plants and antagonists for more effective integrated pest management; and incorporating resistance to pests, pathogens and weeds into improved, productive cultivars through classical breeding and biotechnology/genomics. Research activities in this program

area have also concentrated on developing new and refining existing mechanisms and techniques for managing pests of field crops that are economically feasible for producers and are environmentally compatible. Some highlights of accomplishments in this area follow.

- The Center for Integrated Fungal Research was officially established to promote genomic investigations of important fungal species.
- A draft sequence for the genome of the fungus *Magnaporthe grisea* was released for public analysis. This is only the second fungus to have a completed sequence.
- Phase I trials to find effective alternatives for methyl bromide have identified telone-C35, metam sodium and iodomethane as possible candidates in strawberry production.
- The Plant Disease and Insect Clinic has enhanced capability for species identification of fungi through collaborations with the PPIL. The services are being used locally as well as by national and international clients.
- The Micropropagation Unit strengthened its support for production of various sweet potato and strawberry cultivars that are pathogen tested and true to type. Pilot studies are underway to include other specialty crops such as blackberry.
- Extension faculty have coordinated the development of regional pesticide recommendations for vegetable crops.
- The departments of Plant Pathology and Entomology hosted a national meeting of scientists addressing issues related to pests and pathogens of floral crops.
- Scientists have identified a significant proportion (ca. 20%) of the genes in root knot nematode as well as genes expressed at or near the nematode feeding site.
- A specific gene that allows the cyst nematode to degrade plant cell walls was identified. In addition, a panel of host genes that are activated by cyst nematode infection were identified.
- Large EST libraries have been generated for functional genomics of two industrially important fungi; *Aspergillus niger* and *Trichoderma reesei*. Concomitantly, approximately 30 genes have been mapped to a BAC library of the genome of *T. reesei*.
- In a long term study of the biodiversity of wood-decay fungi within the order Aphyllophorales in North Carolina, over 174 taxa were identified and/or collected.
- *Geotricum candidum* was reported as a principal organism in the souring syndrome associated with flooded sweet potatoes.
- Significant changes in microbial community structure were identified as a result of different management strategies. Specific differences were observed in *Pythium* spp. for both population density and activity.
- Investigations of the evolutionary biology of tomato spotted wilt virus revealed the existence of founder effects linked to the geographic site of origin.
- The Center for the Biology of Nematode Parasitism was established to facilitate investigations of nematode parasitism in plants through increased university-industry-government collaborations.
- Computer simulation models have been developed to predict which of several pesticide resistance management strategies will be most efficient at maximizing the sustainability of pest control tactics. These models have been used by the EPA in setting legal restrictions on the use of insecticidal transgenic crops.
- Moths collected from different geographic areas over the season were subjected to stable isotope analysis to determine whether they fed as larvae on C3 or C4 type plants. The majority of the moths collected did not feed on cotton in their larval stages, even when the adults were collected from cotton fields. This unexpected finding has implications for the way we define refuges for Bt resistance management in the Midsouth.
- Important summer weed hosts of tomato spotted wilt virus, which act as a vital reservoir for the virus during late summer and a primary source for infection of the overwintering hosts of TSWV, were identified. This information confirms the important role of summer weed hosts in the epidemiology of TSWV in North Carolina and will be critical to the development of effective management strategies for this devastating virus.
- A procedure for monitoring resistance of Colorado potato beetle to the newer classes of insecticides, which have limited contact activity, was developed and validated.
- Interactions between host plant species and tomato spotted wilt virus (TSWV) isolates were shown to affect survival of tobacco thrips feeding on the infected host plants and their ability to transmit TSWV. A

consequence of these interactions is that TSWV isolates are differentially favored for transmission by different host plant species. To the extent that such interactions occur in nature, they may help to explain spatial and temporal distributions of TSWV strains and may provide clues for management of the virus/insect complex.

- Now boasting more than 1.4 million prepared specimens, the NC State University Insect Collection promotes a broad range of systematic activities in North Carolina and elsewhere in the nation and abroad. Ongoing efforts to develop an online database have made the collection's resources and data more widely known to the public and more accessible to the scientific community.
- Focus on the systematics of the large, diverse insect families Delphacidae and Membracidae has provided new identification tools, improved phylogenetic classifications (with greater predictive value), and new specialists trained to address systematic problems related to planthoppers, treehoppers and their allies.
- Field and greenhouse evaluations of transgenic Bt cottons have demonstrated that the recently registered Bollgard II cottons will not require synthetic insecticides for protection against caterpillar pests.
- The evolution of resistance to Bt in bollworm was studied by determining whether the frequency of major resistance genes had increased over a three-year period. Results suggest that there was no increase in the frequency of resistance genes. The effectiveness of Bt cottons for bollworm control appears more sustainable for grower benefit than original models predicted.
- A plant-by-plant assessment of the relationship between tobacco budworm infestation in tobacco across a range of plant ages and tobacco plant productivity detected no consistent effect on yield or quality of cured leaf. These findings support a growing body of evidence that this insect is only occasionally economically significant in North Carolina tobacco, knowledge that should result in lower insecticide use.
- Detailed studies of the seasonal occurrence and distribution of the tobacco budworm in a mixed cotton-tobacco-soybean-corn ecosystem suggest that tobacco budworm population dynamics are driven by the presence of tobacco. These data are being used to develop models to help predict the development of insecticide resistance in the tobacco budworm in diverse agroecosystems that will be critical to development of best management practices for all crops involved.
- The Center for Integrated Pest Management (CIPM) continued to work with industry, government, grower and nonprofit organizations to fund and manage IPM programs throughout the U.S. The center is working with USDA/APHIS to monitor Internet sales of illegal plants and animals and to create a new secure database of information on global pests and diseases. The center has developed a web-based information system for the new USDA Regional Pest Management Centers and a pest management information and decision support system that allows access to crop profiles, pest management strategic plans, pesticide use and new pest management technologies. It also provides searchable access to IPM experts.
- Relationships between predators of spruce spider mites and ground covers within Fraser fir Christmas tree plantations are being evaluated. The information will be used to advise growers on best management practices to reduce miticide applications.
- The importance of juvabione in Fraser fir for resisting attack by the balsam woolly adelgid is being investigated. This study should lead to directions for tree selection for resistance to this pest.
- Transgenic corn containing two Bt toxins, cryIAb + cryIIAb, allowed almost zero production of corn earworm moths, indicating that this plant type would both be more effective for growers and fit well with EPA's preferred high-dose resistance management strategy.
- Studies on the population dynamics and management of twospotted spider mite in the Piedmont of North Carolina revealed that tomato is a key crop for the buildup and dispersal of mites to other crops and to overwintering sites in the autumn. The development of miticide-resistant populations on tomatoes can therefore have long-term implications on multiple crops, so resistant management strategies are being developed on tomato to ensure the susceptibility of populations to miticides on multiple crops.
- Alternatives to insecticides under scrutiny by the EPA have been evaluated to determine how best to implement reduced-risk pest management strategies on apples. On-farm demonstrations and educational programs have helped growers to implement successfully insect growth regulators, new chemistry pesticides and mating disruption into apple IPM programs.
- A maize protein that has antifungal activity against the aflatoxin producing fungus *Aspergillus flavus* has been identified and shown to impact fungus development and incidence under both lab and field conditions. This

natural seed protein, which is non-toxic to humans, may provide a safe means of preventing fungal damage to maize.

- A training grant was funded by the USDA IFAFS MGET program to provide support for 15 Ph.D. students who will be trained across an interdisciplinary program in agricultural biology.
- Fruit entomologists are evaluating alternatives to organophosphate insecticides for control of plum curculio in apple, peach and blueberry. Avaunt, a new compound from Dupont Chemical Company, appears to give good control with shorter residual activity and lower toxicity to users.
- Gall midge (*Dasineura oxycoccana*) has been identified as a significant threat to fruit set and productivity in rabbiteye blueberries. Entomologists are evaluating biological and chemical control tactics for this new pest.
- Colonies of the invasive Argentine ant were found to be more limited in size and distribution in the Southeastern U.S. than elsewhere in their introduced range, a finding that will help identify ecological factors involved in restricting the spread of this pest.
- An advisory program for reducing the incidence of tomato spotted wilt virus in peanuts has been developed and distributed to growers. On-farm demonstrations indicate the program can lead to a 40-60% reduction in the incidence of this devastating disease.
- Research on the Oriental beetle grub in Western North Carolina has revealed its life cycle varies significantly from that of the Japanese beetle. Since the Oriental beetle has now become the major turfgrass white grub pest in Western North Carolina, this new knowledge allows turfgrass managers to more effectively time environmentally sound pest management products.
- Studies on the use of biological control agents against turfgrass pests has shown that many formulations of these products are not appropriate. While the control agent itself may be very efficacious against a particular pest, the carrier may create a behavioral response of the pest that limits the level of control. Studies are currently looking at novel techniques for delivering the control agents in the turf system.
- A rootworm advisory has been refined that includes decision making guidelines to assist growers participating in an IPM program for peanuts. It has been estimated the advisory will reduce rootworm insecticide use by 50% in some counties.
- Using molecular genetic markers, it has been possible to show that pressure from subterranean termites in the Piedmont of North Carolina is higher than previously appreciated, with several colonies of termites often occurring close to buildings.
- A novel bioassay system was patented and licensed to a company for commercialization to be used for monitoring insect resistance to Bt and chemical insecticides in cotton and other crops, for screening of new transgenic cotton varieties resistant to insects, for high throughput screening for insecticides, and for general entomological research and insect rearing.
- Technology stemming from the discovery of a new insect repellent from a wild tomato plant has been patented and licensed to a company and has been submitted for registration with the EPA for use in devices to repel insects and as a spray-on insect repellent. Other applications have also been submitted for patents, including the use of this technology as a possible replacement for methyl bromide.
- Collaborations between faculty in the Department of Entomology and the Department of Nuclear Science at NC State University produced proof of concept for the use of low-temperature, atmospheric plasma as a novel insect control method.

IMPACTS

Sustaining Transgenic Technology

a. Bollgard cottons that produce an internal insecticidal Bt toxin effective against caterpillar pests such as bollworms, *Helicoverpa zea*, have revolutionized insect management by ensuring against crop losses while minimizing the environmental impacts of insect control. Insect management achieved through this novel type of plant resistance is not only effective, but is much more convenient for the cotton farmer than conventional insecticides and often is more cost effective. If this technology is to be sustained, the evolution of resistance by insects must be delayed. One way to help delay the resistance development is to require that farmers plant refuges of conventional cotton. While the Environmental Protection Agency granted a five-year extension for the general Bollgard registration late in 2001, the 5% unsprayed refuge option will remain in effect only until the end of 2004,

at which time it will be reviewed by EPA to determine whether or not this specific option will be continued. At that time, EPA may require changes in refuge size, structure and deployment. In an effort to determine if temporal and spatial production of *H. zea* from various crop hosts are effective for Bt resistance management, researchers at NC State University in 2002 measured bollworm production from various crop hosts. Larvae were monitored in commercial crop fields and side-by-side plantings.

b. Impact: The initial year of research confirmed that non-Bt crop hosts produce sufficient nonselected bollworm moths to substantially delay resistance evolution. There appears to be no rationale for requiring farmers to plant increased acreages of conventional cotton refuge. In fact, this research suggests that planting a conventional cotton refuge is unnecessary in regions of the cotton belt where large acreages of alternate crop hosts are grown. Elimination of the refuge requirement would relieve cotton producers from the burden imposed by an unnecessary regulatory requirement.

c. Source of Funds: Cotton Incorporated, Monsanto Company, Integrated Pest Management Center (NC State University), Hatch formula funding, state appropriations

d. Scope of Impact: Regional

Protecting Peanuts

a. An increase in the incidence of tomato spotted wilt virus has limited yield for North Carolina peanut growers, while the prophylactic use of insecticides to control southern corn rootworm in peanuts remains an input of questionable benefit. Research at NC State University focused on both these areas. The impact of various management strategies as well as planting date, insecticide use, cultivar selection, tillage, seeding rate and row spacing were all studied in relation to tomato spotted wilt virus. An additional study focused on the incidence of southern corn rootworm injury as related to soil characteristics, variety selection and planting date.

b. Impact: This research and extension effort produced a rootworm advisory that provides sound decision-making principles for southern corn rootworm insecticide use. While no new surveys on pesticide use in peanuts will be conducted in the next two years, grower testimonials indicate many have tried the advisory and have been pleased with their ability to avoid unnecessary insecticide use. The tomato spotted wilt virus risk index has been validated and initially presented to growers. Its full implementation will take place in 2003, but research indicates that by selecting the appropriate complement of cultural practices, a grower can reduce the incidence of tomato spotted wilt virus in peanuts by over 50%.

c. Source of Funds: North Carolina Peanut Growers Association, Inc.; U.S. Agency for International Development Peanut Collaborative Support Program; USDA; PMAP in collaboration with Center for Agricultural Policy; Hatch formula funding, state appropriations

d. Scope of Impact: Regional

Managing Pests of Turf

a. Research and extension efforts have focused on using conventional pesticides in the most effective manner and the use and development of alternative control strategies in an effort to develop cost-effective pest management strategies for the North Carolina turfgrass industry while also ensuring environmental stewardship. The key to the use of conventional pesticides in the most effective manner as well as increasing the likelihood of success for biorational products is an enhanced understanding of pest biology and ecology. Research in Western North Carolina has defined the life cycle of the Oriental beetle, studies in Central North Carolina have refined the timing of treatments for green June beetle grubs, research along the coast has provided precise forecasting for mole cricket management and the use of fungal pathogens, while research in the Coastal Plain has allowed the use of newer chemistries to provide improved control of fire ants. A website titled "Turffiles" has been used to provide timely dissemination of this research information to stakeholders. At the same time, the Center for Turfgrass Environmental Research and Education was fully implemented.

b. Impact: Control of Oriental beetle grubs has improved dramatically due to new knowledge on its life cycle. The use of more environmentally friendly pesticides for green June beetle control is now possible as a result of studies in Lee County, North Carolina. Mole crickets can now be effectively managed for less than \$150 per acre as compared to the standard of \$315 just two years ago. New chemistries are providing control of fire ants for up to one year as contrasted to similar approaches yielding one to six months worth of control. The Turffiles website is receiving more than one million hits per years and five of the 10 most frequently requested queries are insect pest related. The Center for Turfgrass Environmental Research and Education became fully operational with

\$600,000 as an initial base for supporting turfgrass research and outreach. Initial funding supported more than a dozen projects in 2002.

c. Source of Funds: North Carolina Turfgrass Foundation, Center for Turfgrass Environmental Research and Education, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Protecting Corn and the Environment

a. In the spring, corn growers throughout North Carolina attempt to establish an optimal population of evenly spaced seedlings in order to optimize yields of grain or silage. Many insect pest species attack planted corn seed and corn seedlings, killing or injuring the young plants. Prediction of damaging infestations is very inaccurate, and growers often use a prophylactic application of granular insecticide applied into the seed furrow with the corn seed to kill pest insects that threaten planted kernels and seedlings. Many of the insecticides used are 25 to 35 years old and belong to the phosphate or carbamate classes of insecticide chemistry. These classes have been in disfavor with the Environmental Protection Agency due to negative human health and environmental profiles. Also, due to their long use history insects are evolving resistance to these and other similar insecticides. In 2001 a project was begun to explore the potential for using new generation insecticides, called neonicotinoid insecticides, as seed coatings applied to corn kernels as protectants for kernels and seedlings. These products are water soluble, systemic within plants and effective against a wide array of corn insect pests. Preliminary data from laboratory, greenhouse, and field microplots in 2001 indicated that two chemicals, clothianidin and imidacloprid, may perform well against southern corn billbug, an important corn pest in North Carolina. In 2002 tests were planted into commercial cornfields at five sites in Eastern North Carolina. Three neonicotinoid seed coatings (clothianidin, imidacloprid and thiamethoxam) were used at multiple rates against southern corn billbug and wireworm. The tests showed very high activity with the clothianidin and thiamethoxam. Rates of 0.25 mg/kernel and 1.25 mg/kernel were established for wireworms and billbugs, respectively. Grower and company tours were conducted to facilitate the development of marketed seed coatings at rates suitable for North Carolina conditions. Results have been shared with interested parties and numerous talks have been presented to grower and farm advisor groups.

b. Impact: These products will be cost effective, safer and more convenient for corn farmers to use. They will also have an environmental benefit by reducing use by 92% to 98%. Wide-scale replacement of older products is anticipated.

c. Source of Funds: Corn Growers Association of North Carolina, Bayer Crop Sciences Company, Gustafson Company, Syngenta Company, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$889,684.82	\$7,685,348.59	\$3,825,680.45	\$2,148,307.29	36.41	60.89	69.02	40.44

**Goal 1, Program Area 4:
Animal Diseases and Animal Health**

Overview

Research activities in this program area have concentrated on improving overall animal health and performance through methods that reduce the incidence and/or severity of diseases caused by pathogenic agents and/or other environmental factors; developing environmentally safe, economically realistic, and socially acceptable methods for the handling and recycling by-products of food animal industries; and developing effective, safe and acceptable practices for the control of odor and pests associated with food animal production. Some highlights of accomplishments in this program area are listed below.

- Three long-term studies examining alternative molt programs for laying hens have been completed, and the information presented at scientific and industry meetings. A new study using a positive and negative control is

being conducted to evaluate two specific alternatives to long duration fasts. These experiments included a survey of the microbial shedding of laying hens subjected to alternative molting programs.

- Studies provided a strong indication that the genetics of poultry can have serious implications for disease resistance or susceptibility. It is also clear that poultry breeding companies must consider immunocompetence as a co-selection criteria while selecting birds for performance characteristics such as growth.
- Keratinase digestion of bovine spongiform encephalopathy (BSE) and scrapie prions was tested in ID-Lelystad, the Netherlands, by instigation and financial support of an investigator at NC State University. Full enzymatic degradation of the prion protein PrP^{Sc} in BSE- and scrapie-infected brainstems was shown to be possible under certain pretreatment conditions. Since then, several other enzymes, such as proteinase K and enzymes in the subtilisin-family, were also found to be effective.
- Using comparative sequence analysis, researchers have determined the structure of RNase P RNA in Archaea, a group of organisms that are a missing link between bacteria and eukaryotes. These RNA elements are prime targets for the development of antimicrobials.
- Selenium yeast (selenomethionine) provided in the feed of broiler breeder hens resulted in the production of more hatching eggs than were produced by hens fed inorganic sodium selenite. Additionally, selenium yeast increased fertility and the hatch of fertile eggs. Selenium yeast supplementation resulted in more chicks produced per hen housed. These studies demonstrate that the organic selenium in selenium yeast is a superior form of selenium for supplementation to poultry breeding stock.
- Fermented soybean feed provided at a constant dosage showed some positive effects in birds challenged with coccidial parasites as well as in clean birds grown in cages, indicating that fermented soybean feed may play a role in future health maintenance programs for broiler chickens.
- Studies have tentatively established that the use of probiotics does not affect the maintenance requirements of treated mice, including energy expenditures of the intestinal tract. This conclusion was reached after examining whole body and intestinal energy expenditures of mice fed diets formulated with and without three ionophore antibiotics. This finding represents the first step toward the development of a mechanistic rationale for the use of probiotics as a replacement for prophylactic antibiotic feeding.
- A neonatal piglet model has been developed to examine the pathology of human Norwalk viral infection.
- Preliminary work indicates that *Campylobacter* species contamination levels are quite variable in turkeys, that several *Campylobacter* species are present in different turkey flocks, and that the anti-microbial resistance patterns of the bacteria involved are also variable.
- A list of all species of fleas and lice held by the NC State University Insect Collection will soon be on line at <<http://www.cals.ncsu.edu/entomology/Museum/Homepage.htm>>.
- Darkling beetle and house fly transmission of Turkey Coronavirus (TCV) is limited to 1-12 hours post exposure. Transmission of TCV by house flies was density dependent as 50% of turkey poults became infected with virus at densities as low as one fly per bird. Strict biosecurity measures including house fly and darkling beetle management are essential to managing the spread of TCV during outbreaks.
- A combination of genetic, biochemical, thermodynamic and spectroscopic methods have been used to elucidate mechanistic and molecular recognition features of proteins involved in bacterial regulatory and protection processes. A method of inhibiting stage 0 sporulation in *Bacilli* bacteria by disrupting the action of the Spo0F protein has been developed. This work may provide a method for preventing the lethal bacteria, *Bacillus anthracis* (specifically anthrax) from getting to their pathogenic states.
- Research focused on identifying quantitative trait loci associated with resistance to *Fusarium verticillioides* and to accumulation of fumonisin, the mycotoxin the fungus produces. The data indicate that genes controlling resistance to fumonisin accumulation and fusarium ear rot are segregating in the population. Thus, it should be possible to map QTLs for resistance to these two traits. The ability to associate QTLs with resistance will greatly enhance the breeding of resistance corn lines.
- All the genes from the Porcine Reproductive and Respiratory Syndrome virus have been cloned and expressed in an attempt to identify the best vaccine candidates for this virus, which threatens swine populations world wide.

IMPACTS

Protecting Trout

a. In 1996, enteric redmouth was considered the North Carolina trout industry's No. 1 disease, causing losses of 14 to 20% annually. The traditional recommendation for protecting trout from ERM was to immerse fingerlings in a solution of a killed bacteria. Then, however, research at NC State University showed that injection vaccination provides better protection. Immersion provided only six months of protection for 80% of the fish. And the 20% that were not affected are the ones most vulnerable to the disease. Injection, on the other hand, protected for the life of the fish, and it protected nearly 100% of the fish.

b. **Impact:** The injection process is laborious, and it costs more than the immersion vaccine but far less than the after-the-fact antibiotics that growers had relied upon to treat the fish that immersion didn't protect. About half the trout raised in North Carolina are now injection vaccinated. Losses to ERM have dropped to less than 1%, and growers have cut use of antibiotics by 86%.

c. **Source of Funds:** Hatch formula funding, state appropriations

d. **Scope of Impact:** North Carolina

Toward Better Fed Birds

a. Modern poultry, both broilers, layers and turkeys, are unique animals in that they have been so intensively and successfully selected for production traits that they exhibit a deficit in the function of those organs and processes that supply nutrients from the gastrointestinal tract in relation to the tissues that are nutrient-demand driven and directly involved in the economically important portions of the animal's body (i.e., muscle and egg). This has caused an increase in the susceptibility of flocks to disease and poor performance due to even the slightest deviations from detailed production practices and biosecurity, which puts an added economic strain on an already expensive and low profit poultry operation. The problem continues to grow with the introduction of ever improving genetic stock bred for muscle or egg production. Research has pioneered the use of naturally occurring gastrointestinal peptides to enhance both the rate and efficiency of nutrient uptake from the intestinal tract of broilers and turkeys. In addition, studies have found that administration of nutrient absorbing peptides, such as peptide YY, *in ovo* can increase nutrient absorption and post-hatch performance in both broilers and turkeys.

b. **Impact:** The continued development of peptide technology has offered the poultry industry tangible hope for methods of dealing with gastrointestinal insufficiency and enhancement of health and productive performance in flocks.

c. **Source of Funds:** F.R.I.E.N.D.S. of Trisomy 21 Research Inc., Syntex Corporation, Hatch formula funding, state appropriations

d. **Scope of Impact:** National

Making Dairy Farmers More Profitable

a. The North Carolina Cooperative Extension Service provides North Carolina dairy farmers with research-based recommendations on use of feeds, feed formulation services, feeding strategies and the effects of mycotoxins on animal health, production, reproduction and profits.

b. **Impact:** Using these recommendations, dairy farmers have been able to manage feed mycotoxin problems and optimize feeding efficiency. Dairy farmers have realized increased annual profits of approximately \$100 per cow. Treatment of mycotoxin problems has resulted in improvements of 2 to 8 pounds of milk per cow per day, and improvements in health and reproduction. Even with partial participation by farmers, these programs have the potential to increase the profits of North Carolina's dairy producers by \$10 million annually.

c. **Source of Funds:** Hatch formula funding, state appropriations

d. **Scope of Impact:** North Carolina

Understanding Xenobiotic Exposure

a. Research has shown (via multigenerational studies in mice) that the epigenetic changes induced by the demethylating agent 5-aza-2'-deoxycytidine are transmitted to subsequent generations. Further, tissues of affected F2 offspring have an increase in global DNA methylation, suggesting an over-compensation phenomenon occurring in the dams in an attempt to correct the adverse decreases in DNA methylation induced by the

compound. Research also demonstrated that in utero exposed F1 mice are more susceptible than exposed females to altered reproductive capacity and growth retardation. Further, studies demonstrated that the decrease in male reproductive activity is largely due to abnormal reproductive behavior, and the phenomenon seen in the exposed males is associated with a decrease in serum IGF-1 (this decrease was not seen in the females).

b. Impact: This demonstration of the ability to transmit abnormal epigenetic information to future generations (with subsequent morphological defects) has a highly significant impact on the understanding of how xenobiotic exposures in an individual can potentially affect future generations and how this may make these future generations more susceptible to xenobiotic exposures and other insults. The use of molecular strategies to determine patterns of expression associated with xenobiotic exposure will provide molecular biomarkers of exposure to enhance risk assessment endeavors.

c. Source of Funds: Hatch formula funding, state appropriations

d. Scope of Impact: International

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$493,525.26	\$2,120,111.12	\$1,038,062.41	\$393,587.92	7.61	28.86	17.68	8.57

Goal 1, Program Area 5: Farm Business Management, Economics and Marketing

Overview

Research in this program area has concentrated on improving the economic decision making abilities of the various agents who engage in the production, processing, marketing and management of agricultural products (food, fiber, forestry and ornamentals) grown and/or marketed in North Carolina; increasing the readily available decision making information to participants in the production and marketing process; and identifying socially optimal environmental enhancement (or degradation) and environmental/health risks and the least-cost policies and regulations for achieving policy objectives. Some highlights of activities in the area follow.

- To encourage research and education, the first “North Carolina Summit on Natural Medicinal Products” was organized and held in Chapel Hill in September, 2002. Experts in health, agriculture, medicine and business presented information about the natural medicinal herb industry.
- A study assessing farmer attitudes toward corn genetically engineered to be resistant to corn rootworm found that while farmers placed a positive value on the additional human and environmental safety that this new corn will provide, they also placed a high value on the reduced yield risk provided by this crop.
- County-level data on tobacco production and quota lease rates have been gathered and statistically analyzed. The analysis gives insight into how production within North Carolina might relocate if restrictions on quota transfer were lifted.
- A spreadsheet decision aid was developed that determines maximum bid price for replacement livestock purchases. This information has proven valuable to producers who seek to make sound business decisions about their dairy operations.
- A Land Preservation Notebook was published and Web site developed that provide information on federal and state laws and programs related to land preservation. Many programs were delivered to educate landowners and the public about voluntary agricultural district programs, conservation easements and other land preservation issues.
- A major effort was undertaken to provide farmers, extension agents, lenders and others with information about the 2002 Farm Bill, new commodity programs in the bill and how to determine the best course of action when establishing acreage base and program yields to maximize expected payments from the program.
- Underlying trends in soybean and corn production and their relative costs of transportation and production for the U.S. and South America and for the Southeast region of the U.S. have been compiled and estimated. This information has been used to highlight and explain the economic forces leading to significant changes in

soybean production and trade. The results suggest that North Carolina will likely supplement domestic soybean product supplies with South American sources under current and foreseeable market conditions.

- Research was completed to estimate the impact of the turfgrass industry on North Carolina's economy using 1999 data. Over \$1.22 billion was spent in North Carolina to maintain nearly 2.14 million acres of turfgrass. The total economic effect of the turfgrass industry's contribution to North Carolina's economy in 1999 was estimated to exceed \$3.4 billion in maintenance expenses and \$1.2 billion due to the purchasing and leasing of turfgrass equipment. In addition, the total value added of North Carolina's turfgrass maintenance expenses was \$2.2 billion and the value added of the equipment expenses was \$278 million. The total employment effect of this industry was estimated to exceed 96,000 permanent and temporary jobs.
- Approximately 1,500 professional tax preparers attended 12 two-day tax schools across North Carolina and nearly 400 professional tax preparers attended 10 day-long workshops. These schools provided current information and interpretation of regulations relevant to the tax management and preparation of complete and accurate income tax returns for agricultural producers.
- Research analyzed different types of contracts between broiler growers and integrators and the payment mechanisms in the contracts.
- A new, economically-sound methodology using capitalized cash rental rates for determining agriculture use valuation for property tax assessment was developed. This method was included in legislation passed by the North Carolina General Assembly in 2002. Total tax savings to landowners as a result of this legislation run well into the tens of millions of dollars. A secondary benefit of this new procedure is the restoration of confidence by landowners in the process used by county tax assessors and county commissioners.

IMPACTS

Assessing the Tobacco Program

a. Economic models of the impact of elimination of the tobacco program were updated. Feedback and comments were provided to congressional offices and farm groups on buyout proposals introduced as bills in 2002. A major educational effort was conducted to keep growers and quota owners updated on current progress and potential impacts of a tobacco buyout. Numerous grower and commodity group meetings were conducted, where the latest information on a tobacco buyout was presented. A new Web site was constructed to provide updated information and analysis on a tobacco buyout. Extensive assistance was provided in analysis and formulation of a post-buyout program that was introduced in Senate Bill 3004. Other legislative offices and farm groups were provided assistance in understanding the potential impact of a tobacco buyout. Testimony was given before the House Agricultural Sub-committee on Specialty Crops and Foreign Agricultural Programs. Tobacco producers and quota owners were provided with up-to-date information on a potential buyout and its implications.

b. **Impact:** Policy makers, tobacco growers and tobacco quota owners were given the kind of information needed to make informed decisions about the tobacco program and a possible tobacco buyout. Tobacco remains one of North Carolina's most important crops, and decisions regarding tobacco will have far-reaching effects across the state.

c. **Source of Funds:** North Carolina Tobacco Research Commission, Hatch formula funding, state appropriations

d. **Scope of Impact:** Regional

Analyzing the Master Settlement Agreement

a. Analyses were prepared of the 1) direct economic impact of the Master Settlement Agreement (MSA) on North Carolina tobacco growers and quota owners, and 2) direct and indirect economic impacts of the MSA on related sectors of the North Carolina economy. The lump-sum value (present value) in 1997 dollars of the projected stream of losses attributed to the MSA from 1999 through 2001 to North Carolina burley and flue-cured tobacco growers and quota owners is \$96.9 million to \$112.6 million. The lump-sum value (present value) in 1997 dollars of the projected stream of losses attributed to the MSA from 1999 through perpetuity to North Carolina burley and flue-cured tobacco growers and quota owners is \$654.9 million to \$764.0 million. Impacts on the North Carolina economy were evaluated stemming from both the MSA and the increase in federal and state excise taxes in forecasted employment, output and population over the next 10 years.

b. Impact: Board members of the North Carolina Tobacco Trust Fund Commission, the Governor’s office, state legislators and policy groups used the analyses in formulation of policy for allocation of the state’s Phase I MSA payments.

c. Source of Funds: North Carolina Tobacco Trust Fund Commission, Hatch formula funding, state appropriations

d. Scope of Impact: North Carolina

Evaluating Waste Management Technologies

a. A number of waste management technologies are being considered as potential alternatives to the lagoon and spray field technology now used to manage wastes from most North Carolina swine farms. Cost data from several of these potential alternative technologies were collected and are being used to estimate the incremental costs on the North Carolina swine industry from adoption of an alternative technology to the existing lagoon/sprayfield technology. An economic model of the North Carolina swine industry has been developed and current research is focused on developing parameters for the model in order to simulate the probable impact on North Carolina if producers are required to adopt a new technology or technologies.

b. Impact: The results of this study will be price, quantity and profitability effects of adoption of new technologies, including the impact on different sizes and types of farms. The total cost to the North Carolina swine industry and impacts on local communities from presumably higher production costs will be valuable information to the legislature in its deliberations regarding future regulation of the industry.

c. Source of Funds: NC State University Animal and Poultry Waste Management Center, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Assessing Stormwater Management

a. When urban stormwater is not adequately managed, the environment may be adversely affected. As a result, stormwater best management practices (BMPs) are becoming commonly used throughout the United States. Design engineers and developers must determine the optimum practice for a particular watershed size, land cost and target pollutant. An economic decision making tool was developed to help determine the best BMP to choose for North Carolina conditions given a particular size of watershed, type of watershed as described by curve number range, soil type and pollutant type.

b. Impact: This economic tool is interactive and can be used for the assessment of the optimal BMP for any site-specific condition. The resulting information should be extremely valuable to design engineers and developers involved in stormwater management.

c. Source of Funds: Hatch formula funding, state appropriations

d. Scope of Impact: North Carolina

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		SY	Personnel		
Federal	State	Federal	State		PY	TY	CY
\$220,368.03	\$1,827,161.71	\$175,744.01	\$75,464.66	5.69	3.6	5.98	1.57

**Goal 1, Program Area 6:
 Product Development**

Overview

Activities in this program area concentrated on development of new and improved animal and fruit and vegetable products and reduction of waste through development of by-products. It is envisioned that new products and/or processes will be adopted by industry leading to economic expansion by way of domestic and international sales of North Carolina and other U.S. value-enhanced agricultural products. Some program activity highlights follow.

- Relationships were correlated between strain and thermal histories to develop a process cheese melt-map that will help manufacturers predict relationships of high quality. Thus, industry should be able to control manufacturing conditions to deliver desired product characteristics.

- A procedure was developed for producing brined vegetables with a minimum of waste and with high quality, which involved establishment of a pilot system for potential commercial application. The procedure produces a process-ready, brined cucumber, which should benefit farmers and processors.
- Progress was made in the areas of whey protein hydrolyzate characterization, thermal stability of whey proteins, and characterization of interfacial film rheology. These research findings contribute to the better utilization and design of whey protein ingredients for applications in foams, gels and protein-fortified drinks.
- Progress continues on the development of a non-destructive, non-invasive sensing system that is important in ensuring a high-quality, safe food supply. NIR and visible reflectance values have successfully predicted both storage time and ammonia content of crab meat.
- Two bulk-barn air-curing experiments of VA-539 dark tobacco were conducted on primed leaf from whole plants that were machine-harvested. Research demonstrated that physical and chemical qualities are exceedingly sensitive to microenvironment effects. Nonetheless, the results show that controlled environment air-curing of primed-leaf dark tobacco has the potential for production of tobaccos with acceptable leaf quality and low nitrosamine and sugar levels.
- Previous work demonstrated that the coat protein of the canine papilloma virus (COPV L1) is an effective and safe vaccine, providing immunity against the virus in dogs. The goal of this project is to produce this vaccine molecule in genetically altered tobacco plants and to develop methods to purify the vaccine in commercially useful quantities. The research associated with this project has made substantial progress in achieving its goal. A procedure has been developed to detect COPV L1 in extracts of tobacco leaves, and the work has identified inexpensive solvents that can be used in the recovery of valuable surface leaf components.

IMPACTS

Unraveling the Secrets of Probiotics

a. Clinical evidence supporting the beneficial roles of probiotic cultures is rapidly accumulating, but the specific microbial features, metabolic pathways and properties that are directly responsible for cause and effect relationships have yet to be identified. In order to attack this important area, researchers in the Food Science Department at NC State University are collaborating with a sequencing laboratory at the California Polytechnic State University and the Genomics Research Laboratory at NC State to sequence the genome of *Lactobacillus acidophilus* NCFM, the probiotic culture used in Sweet Acidophilus Milk. Thus far, the project has identified a series of genes that are vital to the survival of probiotic cultures as they travel from food to the gastrointestinal tract. Efforts have succeeded in increasing the expression of genes that evoke tolerance to stress, by stimulus preconditioning, to result in probiotic cultures that are more resistant to acid, hot and cold temperatures, and oxygen stress (hydrogen peroxide). A region was discovered in the genome that is responsible for the organism's ability to metabolize fructooligosaccharides (FOS). These probiotic compounds are naturally found in breast milk and are known to selectively stimulate the growth of beneficial organisms, such as lactobacilli and bifidobacteria, over less desirable organisms (e.g., enterobacteria, clostridia) in the gastrointestinal tract.

b. Impact: The project is now identifying genes vital to probiotic functionality and performance, particularly when delivered through milk vehicles. Genomic efforts directed toward many members of the lactic acid bacteria are revealing the mechanisms through which these organisms preserve our food, colonize our gastrointestinal tract, and evoke some important benefits to general health and well being.

c. Source of Funds: North Carolina Dairy Foundation, Rhodia, Inc., Dairy Management Inc., Southeast Dairy Foods Research Center, Hatch formula funds, state appropriations

d. Scope of Impact: International

New River Birch Shows Promise

a. A new weeping form of river birch called Summer Cascade is being introduced through the efforts of a research program at NC State University. Summer Cascade is easy to propagate, fast to produce, has exceptional adaptability and pest resistance, and an attractive weeping habit. This new selection is ideally produced in North Carolina and has world-wide market potential.

b. Impact: Identification and development of superior plants and germplasm with greater adaptability and pest resistance are contributing to reduced need for pesticides, improved environmental quality and greater value for both producers and consumers. Research at NC State University on selection and development of pest-resistance

has essentially eliminated the need for pesticides to control apple scab, dogwood anthracnose, fire blight, powdery mildew, Japanese beetles and Eastern tent caterpillar on a variety of plants. Sales of Summer Cascade are anticipated to exceed 100,000 units annually with a retail value of over \$5 million.

c. Source of Funds: Golden LEAF, North Carolina Division of Forest Resources, North Carolina Association of Nurserymen, J. Frank Schmidt Family Charitable Trust, Hatch formula funds, state appropriations

d. Scope of Impact: International

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		SY	Personnel		
Federal	State	Federal	State		PY	TY	CY
\$70,895.97	\$1,440,205.66	\$610,052.67	\$230,522.90	6.40	20.91	19.16	9.1

National Goal 2: A Safe and Secure Food and Fiber System

Goal 2, Program Area 7 Food and Fiber Processing, Safety and Quality

Overview

Research activities in this program area concentrated on identifying problems and solutions to quality maintenance in storing and marketing fruits and vegetables, field crops and animal products; ensuring that food products are free from toxic contaminants; and protecting food and feed supplies from harmful microorganisms and naturally occurring toxins. Some highlights of accomplishments are listed below.

- Research indicates that fasting or nutrient restriction for a short period in layers results in lower overall mortality.
- Use of the ethylene inhibitor, 1-methylcyclopropene, on apple storage life improved fruit firmness.
- Preliminary results of foliar applications of calcium to peaches indicate increased fruit firmness.
- Results of tests to determine the effects of tocopherols on lipid oxidation showed that the presence of tocopherols provided little protection to phytosterols or fatty acids.
- Evening primrose seed extract was more effective than a commercially extracted filter cake in controlling oxidation in a bulk oil system and in a water-oil emulsion system.
- A prototype tractor-mounted sweet potato vine remover was built and tested during 2001 and modifications added in 2002 with very encouraging results. Indications are that the removal of the above-ground foliage approximately one week prior to harvest may increase skin adhesion as well as contribute to a significant reduction in harvest labor.
- A high-temperature, short-time surface pasteurization process was evaluated for vacuum packaged, ready-to-eat processed meat in order to reduce cross contamination between raw and cooked foods.
- Heat and freeze/thaw resistance of *E. coli* 0157:H7 and nonpathogenic *E. coli* were enhanced after acid adaptation and starvation. Following cold stress, heat resistance of *E. coli* 0157:H7 and nonpathogenic *E. coli* was decreased while freeze/thaw resistance was increased.
- Results indicate that quantitative competitive PCR assay methods can be used to accurately detect and quantify *E. coli* 0157:H7 without the need for traditional time-consuming plate counts.
- A finite element model of the thawing process for skipjack tuna was used to show that thaw time may be reduced by circulating thaw tank water.
- NMR results suggest that frying oil breakdown with temperature produced two effects. First, oxidation increased oil saturation level with selectivity towards n-3 double bonds and these reduced fatty acids were then converted to aldehydes. Second, triacylglycerides were broken down into free fatty acids and mono- and diacylglycerides via hydrolysis.
- Foodservice Materials for Employees, a six-hour Spanish-language curriculum base on the National Education Foundation ServSafe curriculum, was developed and piloted in four counties. A six-hour English-language course was also developed and has been piloted in South Carolina.

- In the 2002 season, 22 peanut breeding lines from North Carolina were evaluated with 19 lines from Virginia, and eight checks at four sites with two digging dates at each site as part of the Virginia-Carolina Peanut Variety and Quality Evaluation program.
- A nucleic acid sequence-based amplification method for detecting bacterial and viral food borne pathogens has demonstrated potential for use in the food, agricultural and public health sectors.
- Sixty-five percent of *Enterococcus* species isolates from fresh produce demonstrated multiple drug resistance patterns. Data from this study may be used to support risk assessments that seek to elucidate the role of foods in the transmission of resistant strains to human populations.
- In preliminary field tests of four energy-management strategies based on utilizing energy potential of ambient air, total tobacco curing energy was reduced up to 20% in comparison with normal schedules.
- An energy/dry-bulb control system was used in tobacco curing tests in which total curing time was reduced by up to 30 hours and total fan energy was reduced by up to 24% while overall total energy reductions were over 12%.
- Results suggest that colonization by *Campylobacter* is prevalent among turkey brooder hub-growout, single-age, and two-age farms. Different grow-out farms that shared a common brooder hub frequently had different populations of *Campylobacter* at growout.
- A heat and mass transfer model of the cryogenic cooling of shell eggs using carbon dioxide suggests that further increases in the efficiency of gas transfer and cooling rate can be realized in the commercial unit.
- Research on development of sampling and quantification methods for odors is on going and has provided evidence that existing methods of odor collection using tedlar bags are suspect.
- Results from studies of the interactive effects of phosphine treatments, application temperatures, and exposure periods, on susceptible and resistant strains of the cigarette beetle have led the international tobacco industry to greatly change its insect management programs in tobacco storages.
- Alkali-aided processes appear to give higher yield and better functional (gelling) properties from Atlantic croaker than do the conventional washing processes for surimi manufacture.
- The timing of carbon addition to water undergoing treatment to make it potable is critical if pesticide residue levels are to be reduced to levels considered safe to drink.
- Softwood propagation of blueberries with mist will allow growers to propagate the desirable cultivars Sampson and Columbus more successfully than from hardwood cuttings.
- A procedure for predicting dairy losses due to clinical mastitis was developed and shown to be unbiased.
- Incorporation of the high-oleic trait into peanut cultivars is likely to improve the intensity of roasted peanut attribute, but it may also increase the bitter attribute in Spanish genotypes.
- A technique was developed to compute the overall heat transfer coefficients in a triple tube heat exchanger that overcomes the shortcomings of previously developed techniques.
- A protocol was developed for the continuous microwave processing (pasteurization or sterilization) of pumpable foods.
- A mathematical model was developed to determine the residence times of spherical particles suspended in the flow regime of a non-Newtonian fluid flowing through four different configurations of holding tubes.
- New microwave technology employing waveguides has been used to blanch peanuts.
- A patent disclosure was filed on a laboratory extractor designed for selectively extracting polar and non-polar components from oilseeds and other matrices using elevated pressure and temperature.
- Studies of aflatoxin reduction in almonds during processing demonstrated high aflatoxin levels in the reject stream and little to no aflatoxin in finished almond lots after processing.
- Studies are providing important information on metabolic interactions between chemicals in humans. The insecticide, chlorpyrifos, has been shown to inhibit the human metabolism of other chemicals such as the repellent DEET and the insecticide carbaryl. Moreover, it is a potent inhibitor of the human metabolism of the hormone testosterone. Chlorpyrifos oxon, the reactive metabolic product of chlorpyrifos, inhibits the breakdown of the widely used insecticide permethrin by human liver enzymes as does the insecticide carbaryl. This work could have a critical impact on human health risk assessments, on which chemicals will be used during military deployments and on which combinations of chemicals are safe to use.

- Preliminary studies of the HabaGUARD antimicrobial conveyor belt system indicate that the system is capable of inhibiting food-borne pathogens.
- Research indicates that both the contact surface and level of organic matter can influence the survival and persistence of *C. jejuni* and *Salmonella* species on food contact surfaces. The data also suggest that foodborne pathogens such as *C. jejuni* and *Salmonella* species can persist on food contact surfaces for significant lengths of time, which may subsequently lead to an increased risk of cross-contamination between food handlers, ready-to-eat foods, and other food contact surfaces. Moreover, heavily soiled surfaces would be expected to improve the survivability of food borne pathogens, especially some *Salmonella* serotypes, on these food contact surfaces.

IMPACTS

A New Way to Prune Blueberry Bushes

a. With the exception of harvesting, pruning highbush blueberries by hand is the most expensive cultural practice North Carolina blueberry growers face. As a result, growers don't always prune their plants as often as they should. Compromised pruning often results in excessive crop loads with smaller berries that are difficult to harvest. And excess fruit can weaken the bushes and sometimes cause bush death if combined with drought. Researchers at NC State University have developed a mechanical pruning method. Bushes are topped following harvest using a sickle mower.

b. Impact: The cost of mechanical topping is about \$100 per acre, compared with \$300 to \$400 per acre for hand pruning. Excess fruit is seldom a problem on topped bushes, and the fruit is larger, more easily harvested and has a better shelf life when compared to fruit from hand-pruned bushes. Topping configurations were developed that produce yields that are 90 to 100% of yields from hand-pruned bushes. As a result of this research, almost all of the 3,000 acres of blueberries in Southeastern North Carolina are now mechanically topped.

c. Source of Funds: North Carolina Blueberry Council, Inc., Hatch formula funding, state appropriations

d. Scope of Impact: North Carolina

Solving a Pork Processing Problem

a. The swine industry has focused genetic selection pressure on the production of pork with increased lean and decreased fat content. While successful, the composition change has resulted in a practical problem associated with subsequent processing of thin/soft pork bellies into bacon. A recent pork audit estimated that approximately 6% of bellies are too thin to slice, resulting in an economic loss of about \$42 million dollars annually. This problem is exacerbated by the feeding of unsaturated fat to swine in the late grower-finisher phase of production. NC State University researchers examined dietary factors that can be exploited to increase the saturation of pork belly fat and thus increase its firmness for subsequent processing. Specifically, the feeding of naturally saturated fats such as tallow, chemically-hydrogenated fats and conjugated linoleic acid were studied.

b. Impact: Several large corporate swine producers (especially in the Southeastern U.S.) have modified their feeding practices in accordance with the results of this research. Many have purchased analytical equipment to monitor pork fatty acid composition so as to better manage the problem.

c. Source of Funds: North Carolina Pork Producers, Fats and Proteins Research Foundation, North Carolina Institute of Nutrition, Hatch formula funds, state appropriations

d. Scope of Impact: National

Providing Food Safety Training

a. Many food services operators do not have the resources to provide their employees with in-depth food safety training. Educators from NC State University are meeting this need by providing low-cost, high-quality training that is accessible and that can be tailored to meet specific needs. The curriculum used to deliver this training is the National Restaurant Association ServSafe: Serving Safe Food. In 2002, 43 North Carolina counties, representing all regions of North Carolina, sponsored this training. Nearly all counties co-sponsored food safety training with environmental health specialists from their local health departments.

b. Impact: In 2002, 176 training sessions were conducted for 2,216 North Carolina food service workers. In three counties, four Spanish-language food safety training sessions were attended by 55 Spanish-speaking food service workers. Education of food service workers and adoption of safe food handling practices is the primary way to prevent food-borne illness in the food service environment.

- c. Source or Funds:** USDA Integrated Research, Education, and Extension Competitive Grants, Hatch formula funds, state appropriations
- d. Scope of Impact:** North Carolina

Ensuring Fresh Produce Safety

- a.** The adoption by growers of Good Agricultural Practices (GAPs) can help reduce the risk of food-borne illness from fresh produce. In an effort to ensure the adoption of GAPs, NC State University and other Southeast university cooperators initiated a train the trainer program for county extension agents across the Southeast. Over 200 extension professionals have been trained, and over 800 programs, attended by over 24,000 producers, have been presented on the value and importance of establishing a food safety plan following GAPs. The cooperative group has worked with all aspects of the industry across the Southeast. The group is now working with the USDA Agricultural Marketing Service to present preaudit educational programs to growers about the creation, development and implementation of a food safety plan prior to application for GAPs certification and a third party food safety audit by USDA.
- b. Impact:** Educated producers will form the all important first line of defense in assuring fresh produce food safety from field to table.
- c. Source of Funds:** USDA/CSREES Fresh Produce Food Safety Initiative, USDA/CSREES Risk Management Agency, USDA/CSREES Small and Part-time Farmer Program, Hatch formula funding, state appropriations
- d. Scope of Impact:** Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$377,612.49	\$3,083,186.46	\$1,070,954.58	\$440,921.43	14.14	24.52	34.03	11.89

**National Goal 3:
A Healthy, Well-Nourished Population**

**Goal 3, Program Area 8:
Human Nutrition and Human Health**

Overview

Research activities in this program are concentrated on improving human health through hazard reduction and nutrition related to food choices, habits and consumption. The focus has been on food safety issues as related to overall consumer health and well-being. Some highlights of accomplishments follow.

- The host-feeding patterns of mosquitoes collected in the Borough of Queens in New York City were investigated. Knowledge of the blood feeding habits of mosquitoes will be helpful to identify species that should be targeted for surveillance and control.
- Research indicates phospholipids obtained from both animal and plant sources can serve as natural antioxidants to protect the quality and stability of foods.
- Work significantly raised the awareness among migrant workers, growers who employ seasonal farm workers and state government officials of the implications of heat-related illness among agricultural workers.
- Studies continue to explore the role of organophosphorus insecticides as inhibitors of the human metabolism of both xenobiotics and endogenous substrates. However, health risk assessments are currently carried out primarily on the basis of studies on experimental animals, generally rodents. This research demonstrates the need for the integration of human studies into the risk assessment process.
- Methyl tertiary butyl ether (MTBE) is a gasoline oxygenate that decreases automobile exhausts emissions of carbon monoxide and other atmospheric pollutants. Work in progress suggests that MTBE-degrading bacteria can grow on numerous compounds and can be induced for MTBE degradation by MTBE itself. This observation potentially rationalizes why oxygenation of groundwater frequently leads to MTBE degradation. Additionally, studies suggest that the enzyme responsible for MTBE oxidation is a close relative of enzymes

found in many soil bacteria. The significance of this finding is that this enzyme system is known to be widely distributed among bacteria in gasoline-impacted environments.

- Staphylococci are one of the most prevalent bacteria causing infections in humans and animals resulting in morbidity and mortality. Their infections can result in economic losses to agriculture. Once strains or lineages causing the most damage to health can be identified, it should be possible to monitor them using molecular fingerprinting methods to identify their sources and limit their proliferation. Several years of typing such lineages have supported the hypothesis that relatively few lineages are responsible for most infections.
- Research found that the timing of carbon addition to water undergoing treatment to make it potable is critical if pesticide residue levels are to be reduced to levels considered safe to drink.
- Research suggests that the expression of certain genes will influence the efficacy of cancer chemopreventive agents.
- Studies identified important human metabolic pathways for several pesticides and demonstrated that pesticides can inhibit metabolism of both exogenous and endogenous chemicals. Further characterization of these types of pesticide interactions will be necessary to identify a population or individuals who may have greater risks to pesticide exposure.
- Research indicates that exercise during lactation improves cardiovascular fitness levels without impairing maternal immune status or the immunological properties of breast milk.
- Research provided new information regarding the role of estrogen in the sensitivity of female mice to mirex-induced tumor promotion.
- Research suggests that lowered levels of omega-3 and omega-6 fatty acids in red blood cells of older women may be related to depression.
- Studies indicate that intakes of n-3 fatty acids that can be achieved by dietary modifications can decrease the risk of heart disease in postmenopausal women using hormone replacement therapy through a decrease in oxidative stress and inflammatory response and improvement of plasma lipids. This decrease will have minimal side effects and involve minimal costs.
- Research is making a significant contribution to the understanding of colony and population genetic structure in both native subterranean termites and the highly destructive, exotic Formosan subterranean termite. The information will aid in the development of more effective ways to manage these costly economic pests.

IMPACTS

Getting the Most from North Carolina Fruit

a. Fruits and vegetables contain antioxidants that can reduce free radicals associated with degenerative diseases. North Carolina ranks fourth in the nation in blueberry and strawberry production and has significant production of muscadine grapes and apples. However, few of these crops are processed into value-added products. In the processing of such crops as grapes and blueberries into juice and wine, 30 to 40% of the residual material (pomace) is left. This material has been shown to contain significant sources of antioxidants. These valuable raw materials hold the potential to expand the economic base of many North Carolina agricultural communities. Studies at NC State University show that through the application of emerging process technologies, the antioxidant content and overall nutritive value of blueberries and muscadine grape juice and wine can be increased significantly. The goal of this research is to optimize the application of these technologies to retain the maximum antioxidant content of these value-added products without sacrificing sensory qualities.

b. Impact: The development and application of emerging process technologies to improve the quality and number of value-added products obtained from North Carolina fruits and their by-products will increase the economic base of numerous rural communities across the state. By developing further-processing technologies to fully utilize by-products of the fruit growing industries, North Carolina farmers and their rural communities along with food processors may ultimately demand more for their crops, and more North Carolina citizens will be employed in growing, producing and marketing value-added foods and nutraceutical supplements.

c. Source of Funds: North Carolina Grape Council, North Carolina Blueberry Council, USDA, Institute of Nutrition, Golden LEAF, Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Determining the Benefits of Flavonoids

- a. Phytochemicals, particularly those with antioxidant activity, are being treated as palliative, preventative or curative for various chronic diseases and in some cases for general health and well-being. A large class of these compounds, flavonoids, are being used as supplements, nutraceuticals and functional foods, with little or no evidence that they possess any physiological activity. An animal study was completed wherein the flavonoids quercetin, catechin, and epicatechin, (the most widely consumed flavonoids by humans) were tested for their in vivo antioxidant activity. Tissue isoprostanes were used as a measure of in vivo peroxidation. In vitamin E deficient animals, flavonoids offer no antioxidant protection. In vitamin sufficient animals, no additional protection against peroxidation was observed, but serum and tissue vitamin E levels were increased. Since it is known that vitamin E produces other effects besides being an antioxidant (platelet aggregation, blood vessel tone, etc.), this sparing effect on vitamin E may provide the organism other benefits.
- b. **Impact:** The research should be useful to the organizations that establish recommendations on dietary intake.
- c. **Source of Funds:** Institute of Nutrition, Hatch formula funds, state appropriations
- d. **Scope of Impact:** National

New Ways to Manage Ants

- a. The complex of ant species that invade residences and commercial establishments is currently regarded by professional pest control operators as the No. 1 urban insect pest problem in North Carolina and throughout much of the nation. Ants may contaminate food with pathogenic microorganisms, and food visited by ants is often destroyed by consumers and food-handling facilities, resulting in financial loss. Organic landscaping mulches provide favorable nesting substrates for urban pest ants. Research at NC State University has shown that aromatic cedar mulch may be used to reduce Argentine ant and other pest ant populations. This landscaping mulch is both repellent and toxic to Argentine ants and odorous house ants. Research has also determined that aromatic cedar mulch reduces the number of Argentine ant nests around buildings. This research is to be extended by alternating preferred and non-preferred (aromatic cedar) mulches around a residence in an effort to concentrate ants in preferred mulches, so that they can be more effectively controlled by limited quantities of liquid residual insecticides.
- b. **Impact:** By substituting aromatic cedar mulch for other organic mulches, we may be able to limit urban ant populations and the damage caused by these ants. Reducing ant numbers by restricting the areas where they can create nests may also lessen the need for ant control with conventional pesticides.
- c. **Source of Funds:** Industry, Hatch formula funds, state appropriations
- d. **Scope of Impact:** Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		SY	Personnel		
Federal	State	Federal	State		PY	TY	CY
\$197,467.29	\$2,047,323.43	\$543,142.03	\$61,526.86	11.29	13.69	16.76	5.98

**National Goal 4:
 An Agricultural System that Protects Natural Resources and the Environment**

**Goal 4, Program Area 9:
 Soil, Water and Air Quality Conservation and Management**

Overview

The activities in this program area have been aimed at enhancing our understanding of the physical, biological and chemical processes and interactions influencing agricultural and forest ecosystem productivity. Interdisciplinary research projects will advance knowledge of natural processes to enable development of production management and environmental protection technologies that will enhance productivity; improve input efficiency; conserve natural resources; and improve and protect environmental quality. Some program accomplishment highlights follow.

- Laboratory and greenhouse studies designed to assess the potential on-site reuse of graywater from laundry and dishwashing machines of single-family homes indicate graywater has a negative impact on soil hydraulic conductivity and that graywater used for irrigation adversely affects the growth and appearance of ornamental plants. However, reuse of graywater for irrigating ornamental plants with a Ca amendment will result in a substantial saving of drinking water currently used for irrigation.
- Strip tillage with in-row subsoiling to the 40 cm depth and uniform N application produced the highest grain yield in an evaluation of seven soil tillage systems. The evaluation considered various combinations of chisel tillage, strip tillage, presence or absence of cover crop, in-row-subsoil or not, and variable or uniform N.
- Small-scale studies of saprolite and regolith material below the soil were conducted. A comprehensive system for classifying saprolite and regolith has been developed but needs further testing and verification.
- Seven different soil management systems planted to cotton and corn are being evaluated in a Coastal Plain field. Results will be used to further develop tools to identify management zones within a field to variably manage inputs.
- Researchers are evaluating sediments, hydrology and soil properties at a 750-acre Carolina Bay site that is to be restored to a wetland. Similar properties are being noted for natural bays, along with the vegetation, to determine the conditions desired as a result of restoration. New remote sensing technologies are being tested to evaluate sediments inexpensively to identify where the wetland might leak. Detailed hydrologic modeling will be used to test scenarios for restoring hydrology. Experiments will be conducted to identify the fastest ways to restore the natural vegetation.
- Research is being conducted to reduce the excretion of NH₃, odors, P, Zn, and Cu in swine waste through dietary modification using dietary fiber. In addition, investigations have focused on recovering minerals from animal waste that can be refeed to animals, thus reducing the need to import additional minerals. The nutritional work completed suggests the following potential reductions in output by nutrients, NH₃ and odors from swine: odor >50%; NH₃ emission >50%; total N excretion >25%; P excretion >40%; Cu excretion >70%, and Zn excretion >70%.
- Corn processed to remove hulls and germ, both high-fiber components, leaving the endosperm as a feed ingredient for pigs was evaluated as an environmentally friendly swine feed ingredient. Low-fiber feed reduced waste production by 40% and odor emission without negative effects on animal performance.
- A swine waste management system is being evaluated that uses a belt to separate solid and liquid waste and harvest the solid waste, which is then gasified to produce fuel. The remaining ash may then be used as a feed ingredient for livestock, thus recovering P and other minerals. Ash was evaluated as a mineral supplement in a swine diet. Excellent digestibility was noted without negative effects.
- A system was evaluated to recover NH₃ from swine urine and convert the NH₃ to commercial-grade (NH₄)₂SO₄ fertilizer.
- A nonnodulating soybean line was produced from a cross between a nonnodulating parent line and a high yielding nodulating variety. In two field experiments with swine lagoon effluent as N source, N99-3341 produced an average seed yield of 54 bu/ac and accumulated an average of 193 lbs N/ac from effluent N and soil N reserves. Its seed yield and seed N accumulation were 13% and 17% greater (significant at P < 0.05), respectively, than its nonnodulating parent. After introduction of resistance to Roundup herbicide, this nonnodulating variety will be released for use as a receiver crop for N applied to fields in swine lagoon effluent.
- Educational programs demonstrated proper maintenance and management of on-site wastewater systems.
- Studies with elevated carbon dioxide indicated that CO₂ reduces ozone injury by lowering whole plant ozone uptake. Elevated CO₂ and ozone lowered plant water use by about 25%, and studies with soybean indicated that elevated CO₂ will increase water use efficiency and improve the plant's ability to tolerate water stress.
- Research focused on dispersion from large-scale animal production facilities of NH₃ across the region and its return to earth via deposition in the surrounding river basins. Automated sampling systems have been installed that allow measurement of the atmospheric concentrations of a number of gases (including NH₃), and fine particulates (aerosols) that contain NH₃. Initial data suggest that background NH₃ is much lower than expected.
- Several successful height control measures for tomatoes grown in tobacco float beds were developed as a result of research conducted from 1998 to 2000. Field testing of transplants was completed in 2002. This research indicates that several, but not all, of the height control measures can be used without damage to yield or fruit earliness. This

project has verified that tomato seedling production in the float system can be used without damage to post-transplant fruit yield and quality.

- Studies of insecticide movement for products typically used against soil arthropods in turfgrass indicate limited potential for movement of insecticides or metabolites away from the target site.
- Research indicates that a biological control agent (*Beauveria bassiana*) can alter soil insect behavior; however, overall success is affected by many factors in the soil environment.
- The presence of two species of dung beetles, *Onthophagus gazella* F. and *Onthophagus taurus* Schreber, was shown to improve clay and sandy loam soil, increasing P, K, Mg, and the sum of the cations.
- Research indicates that mineralizable soil N determined by standard anaerobic incubation techniques is correlated with corn N response function and may be useful in adjusting N rates for residual soil N. Also, digitized color infrared aerial photographic images were used to predict optimum corn sidedress N rates. This relationship is still being developed, but appears more robust than techniques developed in other states.
- A study showed that differential N application based on historical yield monitor data did not increase corn grain yield compared to uniform N application across the entire field. This was true for seven different soil tillage systems.
- Aerial color-infrared (CIR) photography was used to determine optimal mid- and late-season N rates for corn, and early-season N rates for wheat. Apparent spectral reflectance of corn using the green difference vegetation index produced relatively strong relationships with optimum sidedress N. This relationship was used to develop site-specific late season N recommendations for testing over the next several years. In wheat, a linear model utilizing the green band proved satisfactory for predicting optimum early-season N rates.
- An N recommendation model developed for field soils was adapted for sand-based root zones in turfgrass putting greens. The model appears to predict lower N rates with no effect on forage production.
- Research indicates that the key to developing lines with the capacity for high protein concentration and high seed mass appears to reside in regulating the storage form of N.
- Fertilizer rate and timing recommendations, as well as strategies for precision management, water control and reduced tillage have been developed to optimize returns and reduce runoff. Critical nutrient level guidelines for cotton and for improving recommendations for utilizing alternative liming materials are being developed.
- An N Loss Estimation Worksheet (NLEW) was developed that allows agricultural producers to track BMP implementation and associated N reductions. NLEW allows each county to determine the extent of BMPs needed to meet a mandated 30% N reduction goal for the Neuse River Basin. It is estimated that through the use of NLEW the combined basin reduction was 34%, 4% over the goal, and was achieved a year earlier than expected.
- A Neuse Crop Management Project was completed that showcased and implemented BMPs in the Neuse River Basin. Nutrient management plans were written for more than 100,000 acres, and fertilizer N was reduced by over 10% without affecting yield.
- Soil quality evaluations in a wide range of cropping systems were initiated, with the ultimate goal of developing quantitative, descriptive indicators of inherent soil quality.
- Studies indicated that C and N cycle more efficiently on more well-established golf courses than on new ones, and nutrients reach levels comparable to adjacent undisturbed forest soils.
- Techniques have been developed for restoring and creating wetland habitats. Wetlands created using this technology have many of the values and functions of natural marshes. Research in progress has the goal of quantitatively comparing structure and function of created and restored marshes with natural reference marshes. We are currently studying the effects of constructed brackish-water wetlands on removal of N and P from water draining from agricultural fields and methods for restoring farmland to non-riverine hardwood forest.
- Concurrent microbial N transformations (mineralization, immobilization and nitrification) are being determined in various agricultural management systems to estimate the kinetics of soil available N. Projects include the examination of microbial characterizations in waste-receiving agricultural lands and determination of microbial/turfgrass interactions in controlling N leaching.
- Component relationships in the ANSWERS model were refined and direct links between the model and several GIS databases were created.
- Studies of riparian buffer vegetation type and width on shallow groundwater quality showed reduced nitrate concentrations for wider buffers (15 m versus 8 m) but no significant effect of vegetation type.

- Studies of subsurface drip irrigation with peanuts and cotton in a Coastal Plain setting indicate yield response approximately equal to yields with sprinkler irrigation and significantly better than yields on unirrigated plots.
- Installation of more than 350 BMPs to treat runoff from 9,000 acres of pasture and cropland in the Long Creek Watershed over an 8-year period resulted in reduced erosion and phosphorus, fecal chloroform and nitrogen levels.
- The forestry version of DRAINMOD is being tested for watersheds with non-pattern drainage systems.
- Data collection continued in a paired watershed study in northern Uruguay to determine hydrologic and water quality effects of changing land use from pasture to pine plantation.
- A suite of lumped parameter models was developed to predict the cumulative impact of land use and management practices on drainage water quality in lower Coastal Plain watersheds. These models can be used to predict effects of field scale practices on water quality at the watershed scale.
- Two intensive nutrient balance studies were conducted to quantify effects of in-stream processes on nutrient and sediment loads, one on an agricultural canal and the other on a forested canal.
- Preliminary findings show that the utilization of nutrients in swine wastewater for greenhouse tomato production is a viable alternative to traditional waste management systems.
- Experimental results indicate that the intermittent aeration process is an effective way to remove nitrogen from swine wastewater.
- A finite difference model used to simulate nitrogen transport in duckweed covered ponds indicates that nitrogen removal is diffusion limited.
- Initial analysis of data from the In Stream Lagoon Treatment System indicates the system was able to remove more nitrogen than a typical anaerobic lagoon.
- A prototype under floor belt system for separation of swine waste solids as defecated is now operational, and adjustments are being made to improve its performance.
- A system was developed for skimming duckweed from the water surface to maintain the crop at a desirable density.
- Alternative swine manure management systems being evaluated in North Carolina include: (1) aeration pond treatment of anaerobic lagoon effluent and recycling for flushing manure to the anaerobic lagoon, (2) centrifuging flushed swine manure to remove solids and nutrients, (3) recovery of ammonia from swine lagoon effluent with ammonia stripping tower and condenser, (4) a covered anaerobic earthen digester with biogas utilization, nitrification biofilters, and utilization of effluent for greenhouse tomatoes, (5) a sequencing batch reactor for nitrification and denitrification, (6) removal of swine manure solids and combustion for energy recovery and utilization of ash minerals for diet supplements, (7) solids/liquid separation and liquid treatment in upflow aerated biofilter, and (8) a convex belt system for draining liquids and collecting manure solids from the barn for further processing by black soldier fly larvae to produce a feed supplement.
- A drum screen filter was used to reduce suspended solids and organic nitrogen leaving an aquaculture facility.
- Modifications to an e-nose were developed to make it suitable for determining basic relationships between animal waste odors and relative humidity.
- Collaborative studies on the short term health effects of exposures to low levels of swine odors and dust on humans were conducted.
- Studies of near infrared technology for measurement of nitrogen levels in growing plants have resulted in the design of devices costing less than \$300 that may be effective in monitoring nutrient levels.

IMPACTS

Verifying Waste Treatment Options

a. Advanced swine waste treatment methods often include expensive unit operations such as aeration. Such systems will benefit from separation of manure solids by reducing the organic load that must be treated. The use of these systems will increase the demand for solid separation systems. However, individual producers and farm owners must often evaluate solid separation systems based only on sales literature. Engineers at NC State University developed a protocol for the verification of technologies for separation of manure solids from flushed swine waste under an arrangement with the Water Quality Protection Center operated by NSF International in conjunction with the EPA's Environmental Technology Verification Program. This general protocol was then

adapted to allow verification of a solid bowl centrifuge and then an inclined screen separator. The data from these verification tests will undergo extensive quality control checks. The reports will be widely publicized and available from NSF International and the EPA on their Web sites.

b. Impact: Although this is an ongoing program, these standardized verification tests will provide the industry with the reliable data needed to encourage the use of these separation devices. Both vendors of separation equipment and potential users of this equipment have shown interest in this program.

c. Source of Funds: EPA through a subcontract with NSF International, vendors, Hatch formula funding, state appropriations

d. Scope of Impact: National

Understanding Phosphorus

a. Soil phosphorus has become a major issue because of its negative impact on water quality when discharged to streams, rivers and lakes. Like any chemical element that is strongly bound to soil particles, the potential mobility and environmental impacts of phosphorus cannot be determined by its total concentration in soils alone. Scientists at NC State University are doing basic soil chemistry research to quantify the different chemical forms of phosphorus in a given soil and to quantify fundamental processes affecting retention and release of soil phosphorus into water. Different chemical forms of phosphorus will release phosphorus in different ways, depending on dynamic processes in soils. Researchers developed an advanced analytical method to quantify the amounts of phosphorus in various chemical forms in soils. Soil analysis using this method suggest that the chemical form of phosphorus in a soil regulates its dissolution. Research was also done to determine how phosphorus is released from soils during reduction. Using a phosphorus-enriched soil from the Coastal Plain of North Carolina, researchers found that phosphorus was dissolved in response to reduction, and the rate of phosphorus release to water was related to the rate of reduction. Increased dissolution of phosphate under reducing conditions has been attributed to dissolution of iron-oxide or iron-phosphate minerals and consequent release of associated phosphorus. However, data from carefully controlled laboratory experiments on soil indicated that dissolved phosphate correlated with dissolved organic matter, suggesting that binding of phosphorus to other dissolved components may also be important to phosphorus dissolution. Separate experiments on a system consisting solely of phosphate-laden iron oxide (without organic matter) supported this hypothesis. During chemical reduction of the iron oxide particles, this research found no increase in dissolved phosphate, but rather a decrease that was attributed to formation of a reduced iron-phosphate mineral.

b. Impact: This research is providing new insights on the accuracy (or inaccuracy) of conventional notions of phosphate retention and release mechanisms in soils. Although the conventional models provide a qualitative explanation for phosphorus release under reducing redox conditions, the release cannot be quantitatively predicted. The most accurate assessment of phosphorus discharge to surface waters from agricultural lands will ultimately be based on a sound, quantitative understanding of the fundamental, dynamic soil processes regulating phosphate release from soil particles (in soil, in riparian wetlands adjacent to rivers and streams, or in freshwater sediments). Using a combination of advanced analytical tools and carefully controlled laboratory experiments, this research is providing new insights into chemical transformation of soil phosphorus that affect its mobility and impact on water quality.

c. Source of Funds: U.S. Department of Agriculture, Hatch formula funding, state appropriations

d. Scope of Impact: International

Restoring Streams

a. Stream restoration has been identified as a major need to improve water quality and aquatic habitat in many North Carolina watersheds. Stream bank erosion contributes more than half of the total sediment load in some impaired streams. Several resource management agencies have identified natural channel restoration as a priority for funding and regulatory programs in coming years. In order to use this funding effectively, many questions related to the planning, design, construction and evaluation of natural stream restoration projects must be answered. A fundamental question relating to stream restoration is: How do we determine the appropriate dimensions, patterns and profiles of constructed stable channels so that they will remain naturally stable? The only way to answer this question confidently is to develop a database of physical measurements from reference stream reaches that are currently naturally stable. Information on shape, size and material measured from reference reaches can then be used to design restoration projects that meet hydrologic and biological standards. NC State

University faculty and students initiated a comprehensive research and education program in 1998 to develop the necessary knowledge and teach users how to effectively apply it. NC State University faculty have provided leadership for five major conferences attended by over 1,000 professionals, over 40 training workshops for over 2,000 professionals, and over 35 local grant-funded projects across the state to demonstrate and evaluate stream restoration concepts. Projects range from very small streams in residential communities to large rivers in agricultural watersheds. Many different agencies and organizations participate in these projects by providing funding, personnel, volunteer labor and educational support.

b. Impact: The level of understanding among professional hydrologists, engineers, biologists and natural resource managers about stream restoration principles and applications has increased dramatically over the past four years. Many regulatory and funding agencies are coming together to develop design criteria based on the applied research conducted by NC State University faculty and students. Many landowners and contractors are seeking the expertise at NC State University for recommendations on how to successfully restore impaired stream channels.

c. Source of Funds: Local governments, NC Division of Water Quality, NC Division of Soil and Water Conservation, NC Wildlife Resources Commission, NC Wetlands Restoration Program, NC Clean Water Management Trust Fund, NC Department of Transportation, U.S. Fish and Wildlife Service, USDA-Natural Resources Conservation Service, U.S. Environmental Protection Agency, U.S. Geological Survey, Hatch formula funds, state appropriations

d. Scope of Impact: North Carolina

Assessing Wetland Restoration

a. Highways are sometimes constructed adjacent to or through wetlands. Drainage ditches are typically constructed alongside the highway to lower the water table and provide a stable road surface. The ditches change the hydrology, not only in the roadway area, but also in a strip of land adjacent to the highway. The Department of Transportation is required to mitigate for wetland loss by creating or restoring wetland hydrology. This process is expensive, often exceeding \$15,000 per acre. Wetland mitigation represents a significant cost in highway design and construction. Because several alternative routes must be considered for most highway projects, a reliable, relatively simple method is needed to determine the lateral effect of a highway drainage ditch on wetland hydrology. Methods previously used are based on the theory of steady state drainage to parallel drains. Because the theory available does not address the actual situation of unsteady conditions and a single drainage ditch, very conservative assumptions are usually made, and lateral effects may be over estimated. This could cause mitigation costs to be considerably higher than necessary. Researchers at NC State University conducted a series of simulation analyses with the DRAINMOD model to determine the drainage intensity that corresponds with threshold wetland hydrologic conditions. That is, the drainage intensity that would cause a site to barely satisfy wetland hydrologic criteria was determined. These analyses were conducted for five hydric soils that span the range of hydraulic characteristics of North Carolina soils. Researchers found that the water table drawdown rates for threshold conditions were independent of soil series and could be specified on a county-by-county basis. Once the threshold drawdown rate has been determined for each county, a relatively simple theory, previously developed at NC State, can be used to determine the lateral impact. Field research is continuing to test the methods for three wetland mitigation sites in Eastern North Carolina.

b. Impact: The methods developed in this program can now be used to determine the lateral influence of a highway drainage ditch on wetland hydrology. The methods are not confined to highway drainage and could be used to determine the lateral effects of agricultural and other types of drainage improvements. The result could potentially save millions of dollars in mitigation costs while still protecting our wetland resources.

c. Source of Funds: North Carolina Department of Transportation, Hatch formula funds, state appropriations

d. Scope of Impact: International

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$974,390.16	\$5,940,460.18	\$1,862,215.80	\$1,136,178.78	23.83	50.09	50.52	17.73

Goal 4, Program Area 10: Forest, Pasture, Wildlife and Fish Resource Conservation Management

Overview

Research activities in this program area have concentrated on understanding relationships between soil fertility and plant communities; identifying biological and physio-chemical factors that influence establishment and growth of trees; describing physiological mechanisms controlling reproductive biology of fish; developing improved understanding of the habitat factors that influence reproduction and survival of terrestrial wildlife; and identifying environmental factors that influence the reproduction, recruitment and survival of fish. Some program accomplishment highlights follow.

- Blow-downs (patches of wind-thrown trees) in selected areas of Western North Carolina and Eastern Tennessee were surveyed. The sites were described and documented using GPS technology to enable evaluation and development of methods for monitoring and studying wind disturbances.
- Research demonstrated that habitat corridors promote movement through fragmented landscapes. Although such evidence has been accumulating for animals, this work was the first to demonstrate corridor use by plants and the role of important plant-animal interactions.
- The ecological impact of dung beetles on Coastal Plain and Piedmont pastures continued to be evaluated. Dung beetle diversity represented 25 species and was greatest on the Coastal Plain, while 13 species were collected in the piedmont. The presence of dung beetles significantly improved pasture health and soil condition and reduced pest insects.
- Barbed wire corrals were used to collect black bear hairs from which individual animals could be identified by DNA analyses. Subsequent collection allowed estimation of the number of bears in the population. In addition, 30 bears were captured and tagged with satellite radio collars in order to document movements and locations relative to landscape features. This work is valuable for managing the bear population, which is a valuable hunting resource.
- A combination of hydroacoustics and a fishwheel were used to estimate the size of the spawning population of striped bass in the Roanoke River (about 250,000 fish). To our knowledge, this is the first estimate of run size for a striped bass population. The information will be useful to state and federal agencies responsible for managing this valuable fishery.
- Researchers identified spawning grounds and evidence of spawning activity in red drum in the lower Neuse River, critical steps toward successfully rebuilding the depleted stocks of this important commercial and recreational fishery.
- Lab experiments evaluating the effects of hypoxia (low oxygen concentrations) on mortality and growth of juvenile estuarine fishes show that mortality begins to increase rapidly when oxygen concentrations drop below 1 mg/L and increases with temperature and fish size. Strong reductions in growth rate are evident at 1.5 mg/L but not at 2 mg/L, even though 2 mg/L is still fairly severe hypoxia. These results are being synthesized in a simulation model to evaluate effects of nutrient loading on estuarine fish production.
- Alternative models of habitat selection by stream fish were evaluated, focusing on the problem of predicting habitat selection by fish and other animals faced with conflicting demands of obtaining resources while avoiding predators. This work improves our ability to predict changes in habitat selection when biotic communities are altered.
- Two chemical fate models (EXAMS and EqP) were modified and tested to estimate exposure of atrazine and metolachlor in a small tidal estuary in North Carolina. Both models predicted pesticide concentrations within an order of magnitude of measured concentrations and will allow resource managers to better predict pesticide exposures and risks to aquatic organisms.
- Researchers discovered a hormone that is responsible for sex determination in embryos of the water flea (*Daphnia magna*, Crustacea). This discovery has fueled worldwide attention as it relates to disciplines as diverse as the evolution of sex and pest control.

IMPACTS

Assessing Striped Bass Habitat

a. Recreational freshwater fishing generates \$782 million in economic impact each year in North Carolina. Yet while demand for quality fishing opportunities is increasing, available fish habitat is not. Fisheries managers are

increasingly challenged to maximize fishing opportunities from the available resources. Among the fish prized by recreational fishers is the striped bass, which is often stocked in Southeastern reservoirs. Many of these reservoirs have high water temperatures and low oxygen levels during the summer – poor striped bass habitat. Yet the growth and condition of striped bass are much better in some systems than might be expected. In an effort to understand this seeming contradiction, researchers examined how food availability may compensate for the negative effects of high summer temperatures and low oxygen levels by comparing two reservoirs with contrasting physical conditions and forage availability. This examination included intensive sampling of striped bass and their prey, hydroacoustic surveys of forage biomass, temperature-sensitive radio telemetry of tagged bass, and detailed spatial and temporal monitoring of temperature and oxygen levels

b. Impact: Data collected in Badin reservoir indicate that during some summer periods the lake is completely devoid of temperature-oxygen combinations considered suitable for striped bass, yet striped bass growth and condition are better in Badin than in most North Carolina reservoirs. In contrast, Lake Norman has at least some habitat considered suitable throughout the summer, yet striped bass growth and condition are poor there. Sampling thus far indicates that forage fish availability is much higher in Badin than in Lake Norman and appears to compensate for the poorer physical conditions in Badin. Ongoing bioenergetics modeling simulations will determine how these factors interact to govern striped bass growth and will provide a predictive model that managers can use to make appropriate striped bass stocking decisions. This research has specific benefits for North Carolina striped bass management and general implications for understanding and managing habitat limitations on fish populations.

c. Source of Funds: North Carolina Wildlife Resources Commission, Hatch formula funding, state appropriations

d. Scope of Impact: Regional

Providing Better Habitat for Trout

a. Fecundity, reproductive chronology, physical habitat, water quality, trout density, food availability, diet, predation and competitive interactions among four regulated, or dammed, river reaches were compared to identify ecological factors influencing trout reproductive success. Findings indicated that differences in trophic conditions occur among reaches that limit the potential for trout production and can explain the causes for reproductive failure in some areas. Researchers suggested that management efforts include refining the multi-species trout stocking regime to improve production efficiency, enhancing water flow regulation via dam operations in regulated rivers, and increasing habitat complexity to increase invertebrate and fish productivity for improved natural reproduction and increased abundance and quality of natural trout.

b. Impact: The state and federal agencies that manage regulated rivers in the region have expanded the river rehabilitation program and closely scrutinized and adjusted their fish stocking programs, based on the results of this research. They are implementing rehabilitation structures throughout one large-river ecosystem. These management activities will lead to sound and efficient management of regulated rivers and associated fisheries.

c. Source of Funds: U.S. Fish and Wildlife Service, Arkansas Game and Fish Commission, Trout Unlimited, Hatch formula funding, state appropriations

d. Scope of Impact: Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		Personnel			
Federal	State	Federal	State	SY	PY	TY	CY
\$142,727.12	\$1,731,149.94	\$1,180,682.24	\$308,857.72	5.88	12.74	8.36	6.26

National Goal 5: Enhanced Economic Opportunity and Quality of Life for Americans

Goal 5, Program Area 11: Individual, Family and Community Economic Development and Quality of Life

Overview

Activities in this program area included studies on rural community change, children and youth at risk, community development and youth development. Some program accomplishment highlights follow.

- Research on the allocation of new jobs among different groups within North Carolina communities showed that most county employment growth (70-80%) during the 1980s was accompanied by changes in commuting flows. Evidence also shows that labor force growth (and by extension, population growth and associated fiscal impacts) in rural counties is sensitive to employment growth in nearby urban counties. These results highlight two (opposing) forces related to spatial spillovers that are usually neglected in analyses of the economic and fiscal impacts of employment growth.
- Researchers have examined how consumers feel about biotechnology, and more recently, have analyzed how the food industry is managing the challenges and opportunities associated with biotechnology. Information from this research has been used by government agencies in setting policies and regulations related to biotechnology. The food and agricultural sectors have also used this research to develop and evaluate strategies for promoting consumer understanding and acceptance of biotechnology. The ultimate impact of this research will be to improve domestic and international market potential for U.S. grains.
- Farmers named Gold Star Growers by the North Carolina Department of Labor's Division of Agricultural Safety and Health, identified farm vehicle public road crashes as one of their top safety concerns several years ago. A survey conducted in 1999 showed this to be a common concern of many North Carolina farmers. The Division of Agricultural Safety and Health and its advisory group, The North Carolina Agricultural Safety Council, placed a high priority on addressing this safety concern. The Division has sponsored slow moving vehicle signage giveaway programs for farmers and has provided public road safety education and training.
- Data from privately operated drug and alcohol treatment facilities in 19 of 56 contiguous counties of Eastern North Carolina (26 had none) show that an average of 28% of clients commute across county lines, with both urban and rural counties showing substantial rates of commuting for treatment. The level of commuting clearly could impact funding and level of services provided, which policy makers and government officials need to consider in making program recommendations.
- Findings from the third national longitudinal survey of public perceptions of food, farming and the environment show that Americans strongly prefer their food to be grown and processed in the U.S. and that it be produced locally. Three of four say we should not get our food from other countries even if it costs more to buy U.S. produced food. There is much public trust in farmers and professors for food safety information and in USDA, FDA and EPA. However, there is little trust in elected officials, business executives, or celebrities or in foreign governments for food safety information. Concerns for food safety increased dramatically after 9/11. Regarding the environment in which food is produced, opinions remain strong that the environment should be protected, even if it means higher food prices. About half are undecided as to whether they favor foods produced using biotech or genetic modification techniques, but nearly all say they want such products to be labeled as such. Many opinions can be compared longitudinally across the 1986, 1992 and 2001 surveys to show changes and trends in American public opinion toward food, farming issues and environmental issues. The information from this survey will be used by local, state and federal policy makers involved with farm practices, markets, food safety, biotechnology and the environment.
- A socioeconomic study of La Crosse encephalitis was completed. Disease case patients were interviewed to assess the economic and social impacts of the illness. The socioeconomic burden resulting from LACE is substantial, which highlights the importance of the illness in disease endemic areas of North Carolina, as well as the need for active surveillance and prevention programs for the vector/virus complex.
- A study estimated the impact of changes in state and local tax rates and public spending on economic growth in North Carolina counties. Net impacts on economic growth of combinations in tax rates and spending were derived, something not accomplished in previous work. The study indicated that increasing tax rates to make additional expenditures on higher education results in faster economic growth, while increasing tax rates to

make additional expenditures on transfer programs results in slower economic growth. Changes in K-12 educational spending were found not to be related to economic growth.

- The potential of using only simple statistical models for forecasting retail livestock prices that do not otherwise incorporate the role of economic theory in the model specifications has been examined. Ongoing research as part of this project examines the role of microeconomic theory in monthly retail meat price forecasting performance. Initial results indicate that theory is important, but that simpler models generally forecast as well or better than more elaborate specifications.
- Models were developed to analyze grower decision-making processes regarding a variety of production practices. The focus was on peanuts, one of the most important cash crops in depressed Northeastern North Carolina. The Food Quality Protection Act (FQPA) will result in restrictions in the use of certain key pesticides for pest control in the very near future. Closer scrutiny of pesticides used on foods consumed by children has given additional incentive for peanut production practices to utilize the most advanced Integrated Pest Management (IPM) techniques to reduce any unnecessary pesticide use. Utilization of these models will enable us to design educational programs and market decision-making tools such as the southern corn rootworm advisory.
- Research indicated that local police in North Carolina display a high level of race disparity in making traffic stops even after adjustments for driving behavior and other status characteristics are considered. The North Carolina State Highway Patrol is associated with a much smaller racial disparity in stops. This survey found that respondents under-report police stops; nevertheless the survey data may be used to estimate degree of racial disparity in stops. Finally, trust in the police is undermined by excessive and disrespectful police stops of both white and African American drivers. The basic science generated by this project is being used by the U.S. Justice department in its ongoing investigations of racial profiling.

IMPACTS

Making the Workplace Safer for Teens

a. The National Institute for Occupational Safety and Health (NIOSH) estimates that more than 21,000 teen work-related injuries and illnesses result in lost work days and that 64,000 teens are treated for work-related injuries in emergency departments annually. Injury and fatality statistics show that construction jobs are among the most dangerous. Workers are overwhelmingly male and divided into skilled and semi-skilled trades. An unpredictable work environment complements hazard exposure from tools, machines, materials and other workers. Many teens work as construction laborers or helpers, especially during school vacations. In an effort to better understand teen workers and their work environment, two random samples of teens under 18 working for construction firms were selected from work permits filed with the North Carolina Department of Labor for summer 2000 and 2001. Questions asked via telephone surveys addressed tasks, equipment, working conditions and unsafe working conditions as well as attitudinal and basic demographic items. A survey of young Latino workers and a mail survey of construction employers are in the data collection stage. Results from the telephone interviews show that young workers are in unskilled jobs where they function as handlers, loaders, helpers or watchers. Many perform dangerous tasks and work at places where noise, dust, power tools or heavy equipment are present. Self-reported injury was rare, and concerns about being injured while working were low. Training, though common, is limited, and the use of protective gear not consistent.

b. Impact: Teen construction workers perform dangerous tasks under hazardous conditions with variable amounts of supervision. The results of this study point to the need to examine the training and supervision of young workers and to identify ways to better educate teen workers, parents and employers about child labor laws in order to improve workplace safety and health.

c. Source of Funds: National Centers for Disease Control; National Center for Injury Prevention and Control; National Institute for Occupational Safety and Health of the Centers for Disease Control and Prevention, Hatch formula funding, state appropriations

d. Scope of Impact: North Carolina

Documenting the Black Belt

a. The Southern Black Belt is the largest, poorest and most rural region of the United States. It stretches across 623 counties in 11 southern states. The problems of the historic Black Belt South persist across three centuries and are yet to be satisfactorily resolved. As the nation's largest region, the South holds 36 percent of the U.S.

population, but 41 percent of the nation’s poverty and 40 percent of the adults who have not completed high school. The South also is home to 45 percent of those who live in nonmetro areas and to 55 percent of the nation’s nonmetro poor. It is home to 54 percent of the nation’s African-Americans. Most southern poverty is concentrated in the Black Belt. This research focuses on these issues and seeks to improve quality-of-life conditions in the region. Since 1990, this research has provided basic information and issue awareness, analytic scientific models for solutions to the region’s problems, and a meaningful base for policies and programs to change the longstanding course of the region. This research is transmitted through many publications and over 100 speeches and seminars on improving quality-of-life in the South and Black Belt.

b. Impact: This research and outreach program has had many impacts and spinoffs. It has provided awareness and basic information for scholars, officials, community leaders and citizens about problems of the Black Belt that have been overlooked or ignored since the 1960s war on poverty that focused on Appalachia more than on the larger Old South region. In 2002 the Black Belt Initiative that was launched by the University of Georgia in collaboration with other universities and interest groups moved to an independent organizational status. This effort is based in *The Southern Black Belt* and other products of research focused on demographic and socioeconomic conditions of the historic Black Belt South. The initiative produced a report titled *Dismantling Persistent Poverty in the Southeastern United States*, published in 2002 through the Institute of Government at the University of Georgia. Also during 2002, this research was used in programs by the Federation of Southern Cooperatives, the West Alabama Regional Skills Consortium, Alabama Power, the North Carolina Institute of Minority Economic Development, the Southern Food Systems Educational Consortium (SOFSEC), and other groups. The research was also a basis for the development of the Southeast Crescent Authority (SECA), a regional development commission promoted through East Carolina University.

c. Source of Funds: Southern Rural Development Center, the Farm Foundation, TVA-Rural Studies, Hatch formula funds, state appropriations

d. Scope of Impact: Regional

Expenditures and Personnel Commitments

Appropriations		Grants and Contracts		SY	Personnel		
Federal	State	Federal	State		PY	TY	CY
\$170,272.59	\$1,027,661.50	\$33,733.93	\$9,887.61	5.11	4.17	6.22	3.28

II. Research Stakeholder Input Process

The North Carolina Agricultural Research Service (NCARS) is committed to seeking, receiving and utilizing input from all stakeholder groups, including under-represented groups and the general public. A significant portion of the input from individuals throughout the state comes from interactions of research scientists with county-based extension personnel and directly with producers, industry and other agribusiness representatives. Approximately 100 research faculty also have extension appointments. These faculty are the primary day-to-day communication link between agribusiness, county extension offices and NCARS. Because their research and extension activities are directed toward the development-implementation phase of new knowledge and technology, they are constantly relating industry needs and suggestions to other researchers whose emphasis is more in the discovery phase. In addition, these faculty interact with county extension personnel in such a way that input from individual consumers is also effectively communicated to NCARS administration and faculty.

Stakeholder input utilized in determining research directions is also received through numerous associations. NCARS interacts with 90 official commodity and agricultural industry associations from within North Carolina. A College of Agriculture and Life Sciences administrator is appointed as the official liaison for each of these associations and attends at least one, and sometimes more, of their meetings or conferences each year. During these meetings, opinions and facts related to the needs and concerns of that industry sector are obtained through both formal presentations and informal conversations with attendees. The NCARS representative is always introduced early in the meeting so that any individual there can contact them and discuss whatever issues they desire. In addition, the college has employed a Director of Commodity Relations, who reports directly to the Dean and coordinates the activities of the liaisons. This individual also has responsibility for working with any association that has a need or concern relative to the college's programs, particularly if it might involve any state or federal legislation.

Of the 90 state agricultural industry associations, 24 provide funding to various research projects annually, usually on a competitive basis. In these cases, the association board give NCARS information on high-priority research areas to be used in the request for proposals, and the board decides which proposals to fund. This is the most targeted type of stakeholder input, having a direct effect on research activities within NCARS

NCARS has established an NCARS Advisory Council composed of external stakeholders from diverse backgrounds. The Advisory Council assists NCARS by:

- ❑ Advising the Director regarding North Carolina research needs and priorities.
- ❑ Assisting in evaluation of current and proposed research activities through program reviews.
- ❑ Advocating for NCARS agenda by promoting the importance of agricultural and life science research.

The Advisory Council will meet at least once per year with NCARS administrators, department heads and selected faculty for overviews of research programs and issues, consultation on upcoming state and federal budget items, future concerns, etc.

Many of the departments within the College of Agriculture and Life Sciences have formal advisory groups with stakeholder members that meet on a regular basis to provide input and guidance into the department's research programs. There are 21 such advisory groups among the 18 research departments that meet at least once per year, and their membership includes a total of over 200 stakeholders from a wide range of agricultural interests. In addition, there are currently nine formal centers within the college with industry advisory boards that meet at least twice per year, adding another 60 stakeholders providing NCARS administrators and scientists input and direction from research programs.

NCARS receives support annually from college-based foundations, including the Agricultural Foundation and the Dairy Foundation. These foundations fund research projects and graduate students on a competitive basis across a wide range of areas. NCARS administration meets with the Research and Extension Committees each fall to hear discussion of priority areas for research activity in all aspects of agricultural production and agribusiness. Then in late winter, these committees meet again to select and approve research projects for funding, which provides another opportunity for input on research priorities.

Finally, because the research faculty are also major stakeholders of NCARS, there is a CALS Research Committee, which consists of one elected representative from each department. The committee meets monthly to discuss and make recommendations to the NCARS director relative to policy and resource allocations.

III. Program Review Process

There have been no significant changes in the program review processes since the NCARS 5-Year Plan of Work was submitted.

IV. Evaluation of the Success of Multi and Joint Activities

North Carolina State University faculty were involved in 48 Multistate Research Projects, 12 Information Exchange Groups and 24 Southern Extension and Research Activities. These activities were all multistate, multidisciplinary and involved integration of research and extension. They continue to be an excellent vehicle for collaborative, coordinated research and a broad-based, systematic approach to solving problems relative to the Southern Region and the nation. Examples of multistate, multidisciplinary, integrated activities other than those included above are discussed below.

The National Center for Manure and Animal Waste Management

The National Center for Manure and Animal Waste Management is a collaborative effort of 16 universities. It is supported by a grant for a 4-year period under the USDA Cooperative State Research, Education and Extension Service Fund for Rural America Program. Headquartered at North Carolina State University, the center works to develop and disseminate knowledge and technology that support sustainable, profitable and internationally competitive animal production and also protect community interests and environmental quality.

Center members have produced 21 white papers on major issues affecting animal waste management. These papers describe the state of the science related to each issue and discuss needed research regarding the topic. Center members have also prepared comments on regulations governing Concentrated Animal Feeding Operations proposed by the Environmental Protection Agency. Comments were prepared on the following topics.

- Alternative Technologies for the Management of Manure, Wastewater and Other Process Waters Generated by Concentrated Animal Feeding Operations
- Alternative Technologies for Open Feedlots
- “Zero-Discharge” Systems as the Best Available Technology Economically Achievable (BAT) and the New Source Performance Standard (NSPS) for Concentrated Feeding Operations
- Air Quality
- Nutrient Management Issues Addressed by Proposed CAFO Regulations
- Farm-Level Economic Impact of the Proposed CAFO Rule
- Economic Comments on the Proposed EPA CAFO Rules

Based on the research needs identified by the White Papers, the center sponsored the following nine research projects. These projects were chosen to help provide missing data on topics relating to animal production and waste management. Efforts were made to find projects where National Center funds could be combined with other funding sources to broaden the scope and capabilities of existing projects.

- Whole Farm Management to Utilize Nutrients and Protect Water Quality
- Socioeconomic Issues of Manure Handling Decision Rules
- Decision Support Tool to Estimate Livestock Manure Losses to Water
- Development of a Nationally Applicable Farm Level Budgeting Model of Cost, Benefits and Physical Effects of Selected Manure Management Systems
- The Economics of Co-Permitting
- Impacts of Swine Manure on Water Quality with Emphasis on Antibiotics
- Emissions of Particulate Matter and Ammonia from Cattle Feed Yards and Dairies
- Comparison of Swine Manure Collection Systems and Housing Units
- Manure Production and Composition from Current Swine Genetic Lines

Southern Region Small Fruit Consortium

This consortium is a multistate, integrated activity that includes North Carolina State University, Clemson University, the University of Georgia and the University of Tennessee. Successful recent consortium activities include the following.

- An extension agent training short course on Wine Grape Production at Fletcher, North Carolina brought together 21 agents from consortium member states plus seven agents from Kentucky.

- An extension agent training short course on Bramble Production in Raleigh, North Carolina brought together 19 agents from consortium members.
- The consortium was one of the major sponsors of the joint North American Strawberry Growers Association/North American Bramble Growers association annual meeting in Raleigh.
- A Consortium Web site, housed at the University of Georgia, has been developed and provides information to growers (<http://www.smallfruits.org/>).

The consortium awarded grants totaling \$40,000 in 2002 to fund the following research projects.

- Fungicidal Control of Leaf Spot and Dieback Diseases of Southern Highbush Blueberry and a Detailed Study of Leaf Spot-Associated Losses (University of Georgia)
- Forcing Strawberries for the Thanksgiving/Christmas Holiday Season in Coastal South Carolina with Row Covers: A Third Attempt in an Abnormally Warm Fall/Winter (Clemson University)
- Mite Management in Nurseries and Production Fields (North Carolina State University)
- Virus Detection and Elimination in Blackberry Cultivars Grown in the Mid-South, Mid-Atlantic and Southeastern United States (North Carolina State University, University of Arkansas, Virginia Tech University, Clemson University)
- Evaluation of a Flame Cultivator for Mummy Berry Control in Blueberry (University of Georgia, Auburn University)
- Identification of the Source of *Phytophthora cactorum* Infections in Strawberry Fields (Clemson University)
- Identification of Reservoir Hosts for the Pierce's Disease Bacterium (*Xylella fastidiosa*) in Winegrape Production Areas of North Carolina (North Carolina State University)
- Evaluation of Southern Highbush Blueberry Plants Derived from Tissue Culture and Conventional Rooted Cuttings (University of Georgia, North Carolina State University)

Regional Apple Research and Extension Position

North Carolina State University joined during 2002 with Clemson University, the University of Georgia and the University of Tennessee to create a regional apple research and extension position. This position is focusing on apple orchard management and is interacting with faculty, staff and extension agents from the four universities as well as apple growers from the four states. The position is located at NC State University's Mountain Horticultural Crops Research Station in Fletcher, North Carolina, and much of the research is being conducted there, although field research is being conducted in all four states. The research program is focusing on the use of plant growth regulators to aid in managing apple growth and production and evaluation of promising apple cultivars.

Peanut Variety and Quality Evaluation Program

A cooperative agreement is in place between NCARS and the Virginia Agricultural Experiment Station (VAES) at Virginia Polytechnic Institute and State University for the field evaluation and joint release of Virginia-type peanuts. These peanut selections are primarily bred by NCARS breeders, then evaluated in field trials managed by VAES researchers. Selections are evaluated, selected and approved for release by an advisory board composed of NCARS and VAES faculty and peanut growers and processors. NCARS annually provides half of the funds required to manage the field trials. This program is designed to evaluate the yield, pest resistance, maturity (genetic potential), quality characteristics and consumer acceptance of advanced Virginia-type peanut breeding lines. In the 2002 season, 22 peanut breeding lines from North Carolina were evaluated with 19 lines from Virginia, and eight checks at four sites with two digging dates at each site.

The program also develops research procedures and management systems for the evaluation of peanut lines. Approximately 88% of the peanuts grown in North Carolina in 2002 were of eight cultivars (NC 7, NC 9, NC 10C, NC-V 11, NC 12C, Gregory, Perry, and VA-C 92R) that were developed and released either by North Carolina State University or in cooperation with Virginia Tech University.

V. INTEGRATED RESEARCH AND EXTENSION ACTIVITIES

Research and extension activities are integrated within the College of Agriculture and Life Sciences at the administrative, departmental and faculty levels. The directors of the North Carolina Agricultural Research Service (NCARS) and the North Carolina Cooperative Extension Service (NCCES) work closely together and coordinate all aspects of administration, including position management, state budget requests, budget allocation, facility management and space utilization. Currently, there is an integrated effort to more closely align administrative structure of the directors' offices with programmatic areas across research and extension in the college.

Research and extension activities are integrated formally in a number of key program areas, in which faculty serve in the roles of research and extension coordinator or as a center director of multidisciplinary, multi-function programs. This approach has been particularly successful in water quality, animal waste management, integrated pest management, sustainable agriculture, air quality, small fruits and specialty crops program areas. These coordinator and center director positions are funded by both NCARS and NCCES, and operating funds are allocated from both offices.

In all college departments that have both research and extension faculty, these faculty are housed together and interact on a day-to-day basis in all operational and programmatic aspects of the department. This also promotes close interaction with faculty who teach, most of which have research or extension appointments.

The most complete integration of research and extension occurs at the individual faculty level. Over 70 of the 265 college tenured and tenure-track faculty with research appointments also have extension appointments. In fact, most of these split appointment faculty have 50 to 80% extension appointments, so their research programs are specifically designed to support their extension programs. These faculty serve as a strong link between those faculty who have a majority research appointment (usually split with teaching) and the county-based extension field faculty and state's agricultural industries. Working closely with the more basic, discovery oriented research faculty, these research/extension faculty, in conjunction with county field faculty, bring new knowledge and technology to the producers and agribusinesses through development, field testing and demonstration. In addition, certain faculty with research/teaching appointments have their research activities in program areas that are highly integrated with extension. These faculty work closely with one or more extension faculty to deliver the knowledge and technology gained from their research to clientele. These research faculty commonly give presentations at county agent training sessions, grower meetings and field days. Therefore, project expenditures for these faculty are included in NCARS total expenditure for integrated activity.

Since all research faculty have an approved federal or state research project cataloged on the CRIS database, the NCARS expenditures and personnel commitment for the research aspects of their activities can be documented. The following two tables show 1) the Hatch expenditures and 2) project reports and impacts for 2002 for the integrated projects under the NCARS research program areas and subprogram areas. The total expenditure of \$1,741,663 is 28% of NCARS' Hatch and regional allocation.

HATCH EXPENDITURES FOR 2002
FOR INTEGRATED RESEARCH-EXTENSION ACTIVITIES
 (by National Goal Area and NCARS Program Area and Subprogram Area)

NCARS Program Area and Subprogram Area	Total Hatch
An Agricultural System that is Highly Competitive in the Global Economy	
Technologically Integrated and Sustainable Crop and Livestock Production Systems	
Crop Production Systems	\$326,007.68
Animal Production Systems	\$147,091.41
Biological Systems	\$0.00
Plant and Animal Germplasm, Genetic Resources and Conservation, and Plant Improvement	
Crop Improvement	\$62,955.34
Animal Improvement	\$6,137.28
Plant Protection Strategies (Forest, Agronomic and Horticultural Crops)	\$513,689.45
Animal Diseases and Animal Health	\$0.00
Farm Business Management, Economics and Marketing	\$59,382.06
Product Development	\$4,794.72
A Safe and Secure Food and Fiber System	
Food and Fiber Processing, Safety and Quality	\$20,318.10
A Healthy and Well-Nourished Population	
Human Nutrition and Human Health	\$27,648.37
An Agricultural System Which Protects Natural Resources and the Environment	
Soil, Water and Air Quality Conservation and Management	\$383,393.70
Forest, Pasture, Wildlife and Fish Resource Conservation and Management	\$129,909.62
Enhanced Economic Opportunity and Quality of Life for Americans	
Individual, Family and Community Economic Development and Quality of Life	\$60,335.00
Grand Total	\$1,741,662.73

NCARS Integrated Research-Extension Activities and Impacts (by National Goal Area and NCARS Program Area and Subprogram Area)

National Goal 1: An Agricultural System that is Highly Competitive in the Global Economy

Program Area 1: Technologically Integrated and Sustainable Crop and Livestock Production Systems

Subprogram Area 1a: Crop Production Systems

NCARS #6425 Using Remote Sensing to Manage Nitrogen in a Corn-Wheat-Soybean Rotation

A new nitrogen management system was developed for corn in which multiple applications of small amounts of nitrogen are made at and after planting. The new system was observed to reduce nitrogen requirements by 5 to 10% and increase yield by 20 to 25 bu per acre. Extension meetings and field day demonstrations were used to communicate the new system to growers. Based on surveys at summer field days, over 60% of the growers had adopted the concept of split applications. A conservative estimate of 10% of the state's corn acres realizing increased yield of the magnitude observed would be associated with increased corn acreage income of \$480,000.

NCARS #6466 Development and Refinement of Strategies for Peanut Production in North Carolina

Decreased North Carolina and U.S. peanut production profits creates a need to examine all production and pest management strategies to develop cost-effective, sustainable regional peanut production systems and define their associated risks. Peanuts produced in reduced tillage systems on coarse-textured soils respond equally as well as those produced in conventional tillage systems. But positive response to reduced tillage systems on fine-textured soils may be less consistent. While research suggests that less disease and fewer fungicide sprays are needed for effective disease control in subsurface drip irrigation, expense of installation under the current peanut price structure limits feasibility.

NCARS #6632 Genetic and Production Environmental Influences on Processing and Planting Quality of Nutritionally Enhanced Soybean Seed (Spears)

New soybean breeding lines and varieties developed through traditional breeding and genetic engineering have dramatically altered soybean oil and protein composition. Soybean fatty acids are an important energy source for germinating seeds, and proteins provide amino acids to the growing embryonic axes. Consequently, altering fatty acids, total oil or protein composition could affect germination rate, seedling development and seed storability. Phytotron studies are designed to evaluate the influence of temperature during seed development on subsequent seed quality of nutritionally enhanced soybeans. Seed analysis is underway, and results are being statistically analyzed. Recommendations will result in increased seed quality, allowing seed growers to meet company standards and soybean producers to reduce seed-input costs.

NCARS #6625 Assessing Farming System Sustainability and Research Support for Organic Agriculture Production (Creamer)

Long term cropping systems studies are providing information on important interactions among factors of crop production and inputs that can lead to more sustainable production systems. In a long-term project, five systems (BMP standard, organic, integrated crop-animal, successional ecosystem, plantation forest) are compared. Carbon dioxide evolution varied among the systems (BMP No-Till was the greatest), but seasonal differences were greater than among systems. A three-year experiment is comparing three organic systems (no cover crop; rye-vetch fall planted and incorporated in the spring; rye-vetch fall planted on raised beds and not incorporated in the spring. Some variations in weed biomass were observed, but not differences in yields of organically produced crops in the three systems were observed. Work with allelopathy, different organic systems and understanding biological principles will help growers efficiently produce organic crops for this growing, profitable market.

NCARS #6595 Developing New Crops and Sustainable Production Systems for Vegetables and Medicinal Herbs

In 1998, North Carolina's fledgling medicinal herb industry was valued at an estimated \$27 million. In 2002, after a national three-year slump, the market slowly bounced back. In response to growers' interest in growing medicinals, Cooperative Extension and the Agricultural Research Service initiated studies in 2001 and 2002 on sun-requiring herbs in the Upper Piedmont and on woodland botanicals in the mountains. Extension took several other steps: a) Participated in the North Carolina Summit on Natural Medicinal Products to promote the growth of the industry, bringing together representatives from agriculture, medicine and the natural products industry; b) Initiated a market evaluation for North Carolina herbs and developed a more secure marketing plan for North Carolina growers; c) Helped initiate the North Carolina Natural Products Association in 2002 to provide support and networking opportunities; and d) With the Smoky Mountain Native Plant

Association, helped 13 Graham County growers start commercial medicinal herb plantings, with more than 300 acres now in production.

NCARS # NEED TO CROSS CHECK PROJECT NUMBER

Two priority areas with small fruit production systems are revealing new strategies to sustain and enhance production of both strawberries and blackberries. Diseases in strawberries have traditionally be managed with methyl bromide. With its anticipated disappearance from the market, research has sought suitable, effective alternatives. A number of products, including both synthetic and compost-based treatments, have produced yields comparable to methyl bromide. Work is also progressing to on a new “plug plant” production method that will yield cleaner plants. In blackberries, several viruses are likely associated with decline of plantings. The NC State University MicroPropogation Unit has virus-tested and established in tissue culture virus-indexed nuclear stock of most commonly grown varieties. The N.C. Crop Improvement Association is establishing certification standards, enabling North Carolina to be one of only a few eastern states to certify blackberry nurseries. The methyl bromide findings will help mitigate an estimated \$14 million per year loss to growers, and the blackberry virus work will position North Carolina to become a leading supplier of clean blackberry nursery stock within a year.

NCARS #6196 Influence of Orchard Management on Tree Fruit Growth and Productivity

Educational programs for high-value tree fruit crops growers and potential growers were developed to provide the latest available production information on horticultural management such as cultivar and rootstock selection, optimal cultural management, economics and post-harvest handling. County agents were involved in developing the training and received in-service training and one-on-one training sessions. As a result, traditional fruit growers adopted and planted newer rootstocks in higher-density systems with higher-value cultivars that have a greater potential for consistent cropping and economic returns. Growers planting to higher-density systems are optimizing cultural management with newer pruning and training systems, installing irrigation systems and minimizing weed competition. Many small operations of peach, apple and pecan orchards have been established by full-time farmers looking to diversify, as well as part-time farmers or non-farmers seeking additional income.

NCARS #6623 Processes Limiting Pollen Development and Release Under Heat Stress in Tomatoes and Other Crop Plants

Optimum relative humidity for growing tomatoes was examined under controlled conditions and in combination with high temperatures. Fruit set, percent undeveloped flowers, total fruit weight and percentage pollen germination were most sensitive to high humidity (90%) at high temperature (31/25C), and they were most sensitive to high temperature at high humidity. Overall treatments, optimal vapor pressure deficit was 2.25kPa, and plants grown at 28/22C performed better than those at 31/25C. Enhanced understanding of physiological processes limiting pollen release and viability under conditions of heat stress will allow development of production practices and breeding programs that minimize the effects of heat stress and global warming.

NCARS #6324 Cultural Management of Strawberries and Grapes

This program developed many components of the strawberry plasticulture system utilized in the Eastern United States, including the introduction of strawberry plugs. Plugs continue to rapidly replace fresh bare-root and frigo plants on a worldwide basis. Plug transplants are produced in no more than five weeks, and in warmer growing climates, the process of propagating a strawberry plug can take less than three and a half weeks. Additional benefits include reduced worker exposure to pesticides and lower pesticide residues in strawberry transplants. Several trials were conducted to identify a chemical alternative to methyl bromide fumigation for the strawberry plasticulture industry. Research will further address the development of best management practices for areas that have shorter fall growing seasons and more severe freezes in winter and spring. There is also a focus on the utilization of the latest row-cover technology and a first-time investigation of interaction between-row covers and different plastic mulch films.

NCARS #6596 Production Strategies for Improved Vegetable Production and Alternative Crops for Diversification

Tobacco remains North Carolina’s top income-producing crop, but demand has fallen rapidly in recent years. Growers interested in preserving their family farms must find profitable alternatives. A screening program identifies melons with unique or superior qualities that can be grown successfully in North Carolina and profitably marketed. Several specialty melons have shown good potential, including the Sprite melon. In 2001, gross sales of the Sprite melon amounted to nearly \$1 million for North Carolina producers. A seed-production failure limited acreage in 2002, but sales are expected to top \$2 million in 2003. Meanwhile, screening of other unusual and potentially profitable melons continues.

NCARS #6624 Influence of Orchard Management Systems on Tree Fruit Growth and Productivity

Excessive apple tree crop load in full crop years requires thinning to achieve current year fruit quality (especially size) and adequate return bloom for the following year’s crop. Each cultivar of apple requires a different rate/timing/combination of chemical thinners. Fuji is one of the most difficult cultivars to chemically thin effectively. Recent work has resulted in

acceptable crop load reduction, or thinning. The use of very high Ethrel rates or the use of a new experimental plant growth regulator (Valent BioSciences-30001) at 200 ppm has provided reasonable thinning. Many growers were ready to remove their Fuji orchards, potentially losing production and profit from a very popular and high-value cultivar. Having available commercially acceptable chemical thinner recommendations means growers could retain their Fuji orchards. This new strategy will help reduce hand thinning costs and potentially production and grower income.

NCARS #6515 Crop Improvement Strategies for Ornamental Cabbage and Kale

Fertilization strategies were investigated for ornamental cabbage and kale during center-head coloration. Observations indicated that the normal production practice of terminating fertilization when the center-head began to color was detrimental to overall plant growth. Nutrient deficiencies and lower tissue values occurred within two weeks of fertilizer termination. Continuing fertilization did not inhibit center-head coloration. Greenhouse growers producing ornamental cabbage can optimize coloration and plant quality by fertilization until time of sale.

NCARS #0183 Multidisciplinary Evaluation of New Apple Cultivars

Because of the high cost of establishing apple orchards and changing markets demands, growers must have adequate information to make informed decisions when establishing new plantings. The NE 183 project provides yield and growth data as well as data on susceptibility to fire blight. Several cultivars show promise for the southeast. Pink Lady is an industry favorite and excellent late apple. Zestar is a beautiful early apple, which ripens in late July and has good flavor and red color with a green blush. Jubilee Fuji, now called September Wonder, has good color and flavor and ripens a month earlier than standard Fuji. Ambrosia is an outstanding new apple, similar in color, shape and flavor to Gala, but three to four weeks later, and would be a great addition to roadside markets of shipping with Delicious or Golden Delicious. CQR 10T17 is bright yellow and round with good flavor, is juicy and matures in mid-September. Autumn Gold was harvested two weeks after Golden Delicious and has very nice finish and size with similar characteristics to Golden Delicious.

NCARS #6648 Evaluation of Tillage Practices, Organic Production, and Trickle Fertigation for Nutrient Management in Vegetable Production

Conservation tillage systems, with winter cover crops, have been developed for vegetable growers that reduce or eliminate water and soil runoff from fields. Conservation tillage with synthetic fertilizer and pesticide treatments out-yielded other treatments for both tomato and yellow squash. Leaf petiole nitrate indicated that late season nitrogen was adding to yield of the higher yielding treatment. No-till pumpkins showed a yield response to various types of small grain residue, with greater surface residue increasing yield and quality. Small grain cover crops removed 75 to 250 kg N/ha and 15 to 40 kg P/ha. Sustainable vegetable production requires intensive management and high input levels to achieve acceptable profits and to sustain the soil resource. This project provides information for best management practices for high vegetable yields and improved soil properties.

Subprogram Area 1b: Animal Production Systems

NCARS #6605 Nutritional Strategies to Improve the Growth, Productivity, and Profitability of Dairy Cattle

The average age at first calving among North Carolina dairy herds is about 27 to 28 months, but research shows that dairy producers lose up to \$3 for every day past 24 months of age that calving is delayed. Research has shown that feeding heifers mixed rations with cottonseed hulls can improve growth through consistent nutrition, while improving profits through a reduction of labor costs and reduced age at first calving. The feeding of a high protein milk replacer and calf starter combination is also being evaluated as a means for accelerating growth and, thus, reducing the age at first calving. Reducing the average age at first calving from 27 months to 24 months could save North Carolina dairy farmers \$7 million annually.

NCARS #6496 Genetic Improvement in Pork Production Systems and Understanding Genotype by Environmental Interaction

Genetic selection is a primary driver in advancing the swine industry by improving productivity, reducing costs of production and meeting consumer demand. A genetic advisory committee comprised of individuals from seven universities was formed to develop a comprehensive genetic evaluation system for the Yorkshire, Duroc, Hampshire and Landrace breeds of swine. The average genetic improvements for all four breeds resulted in a reduction of 2.7 days to market and 4.5 millimeters of backfat depth. Other genetic improvements are increases of 1.36 kg of lean per pig and .25 pigs born alive per litter. Twenty-one-day litter weights are up by 1.3 kg. These genetic improvements have resulted in economic increases of more than \$9 per pig.

NCARS #6495 Determining Nutrient Requirements of Swine for Profitable Production

Pork quality is one of the U.S. pork industry's main issues of concern. The total cost per pig from color and Pale Soft and Exudative meat (PSE) problems was \$1.05. Of this amount, 79 cents per pig was estimated to be directly controllable by pig producers. In an industry that produces 98 million swine annually, this amounts to a total of \$77.4 million in losses due to pork

quality problems. Work at NC State University has demonstrated that supplementing magnesium (Mg) to pigs via the drinking prior to slaughter can improve meat quality. It is possible that Mg supplementation will be particularly beneficial in pigs with a genetic predisposition for poor quality meat.

NCARS #6348 Mycotoxins: Contamination of Feedstuffs and Effects on Dairy Cattle

To maximize profits, dairymen must optimize feeding efficiency by increasing milk production per cow through better nutrition and by managing feed mycotoxin problems. The state-sponsored feed testing program is available to North Carolina dairymen and informs them about nutrient content and mycotoxin levels in feed. Cooperative Extension has provided information on feeding strategies and the effects of mycotoxins on animal health, production, reproduction, and profits. Mycotoxins are shown to effect more than a quarter of all dairymen each year. Using extension recommendations, dairy farmers have realized improvements of 2 to 8 pounds of milk per cow per day, and improvements in health and reproduction. These programs may increase the profits of North Carolina dairy producers by \$10 million annually.

NCARS #6451 Forage-based Feeding and Management Systems for Meat Goats in North Carolina

Research and extension activities have examined a number of nutritional and parasite management concerns with goats (potential for copper toxicity; role of liquid nitrogen fertilizer on internal parasites; use of alternative species dewormer products; application of different forage and silvopastoral species as forages for goats; switchgrass related photosensitization; soyhulls as an energy supplement to hay. Data and observations from this research are provided to growers through field days, conferences and other educational activities. This information helps producers select and implement production best management practices that will achieve business, individual and family goals related to profitability and quality of life. North Carolina producers sold over 215,000 meat goats in 2002, generating receipts of over \$9 million. The industry is expected to grow 8 to 10% in 2003. As a part of the program, the Franklin County Goat Producers Cooperative was formed. The cooperative, working with Cooperative Extension, certified 180 members, and it has been the vehicle to market an estimated \$40,000 worth of goat meat through grocery stores, convenience stores and restaurants. Additional income is generated from sales of live meat animals and breeding stock.

NCARS #6602 Integrating Crops and Livestock Systems in North Carolina

Sustainable agriculture research and outreach activities are identifying opportunities for niche marketing, such as direct marketing (green labels, farmers markets and community support agriculture) and organic production. Meat goat production research is evaluating grazing and browsing management strategies. Pasture ecology and controlled grazing management techniques enable farmers to reduce production costs by 20 to 50% without concomitant reductions in animal production. These cost reductions represent savings in the cost of feed and capital investments.

NCARS #6625 Assessing Farming System Sustainability and Research Support for Organic Agriculture Production

Almost complete integration of the North Carolina pig industry has made it very difficult for independent producers to access markets and facilities to slaughter, process and distribute pork. An interdisciplinary, interagency group has assembled, with financial support from Kellogg Foundation, to develop an alternative food system model and implementation plan that supports independent producers and protects the environment, while adding economic and social value to rural communities. The model will represent a partnership of local, independent hog producers and targeted consumer groups that will commit to purchase pork products produced by sustainable approaches.

NCARS #6480 Use of Alternative Supplements in Grazed, Hayed and Ensiled Forage systems for Beef Cattle

The extension ruminant nutrition program increases farm profits by encouraging adoption of byproduct feeds. As a result, in 2001, beef, goat and sheep producers used large amounts of byproduct feeds — more than 6,600 tons of soybean hulls, 3,600 tons of corn gluten feed, 2,500 tons of whole cottonseed, 800 tons of wheat middlings, plus other byproducts — and, thus, saved \$1 million in feed costs. Meanwhile, research and extension efforts continue on feed content of important trace minerals such as copper and selenium; the commercial feed industry has dramatically improved formulas to include recommended levels of trace minerals, and beef producers are adopting good mineral supplement programs by taking part in county cattlemen's association efforts to achieve cost savings by buying recommended mineral supplements in large quantities. In 2002, savings of \$50,000 on mineral and pharmaceutical costs were documented, and that figure is expected to rise as more groups decide to buy supplements cooperatively.

NCARS #6184 Maximization of Laying Hen Performance, Economic Return, and Egg Quality

The North Carolina Layer Performance and Management Test started in 1958, in cooperation with the N.C. Department of Agriculture and Consumer Services and the Primary Breeders of Commercial Egg Strains. In recent years, the test and the support it provides has given the industry an avenue to examine common problems with the environment, management and animal welfare of different strains of Leghorns. With the addition and enhancement of the research to include industry problems and environments, the importance of this test has increased to the industry. Breeders and egg companies use the

test to compare and evaluate the strains and the different environments that are imposed upon them. Breeders have increased their support to cover the costs of research, publications and postage.

NCARS #6343 Nutrient and By-product Utilization and Health of Turkeys and Broilers

Environmental nutrient emissions and enteric health are two issues that challenge the integrated poultry industry in North Carolina. First, economically feasible methods to improve dietary nutrient utilization and recycle animal by-products must be developed and studied. Second, enteric health problems not only reduce nutrient utilization efficiency, leading to increased environmental emissions, but they also account for about 3 to 5 percent of poultry mortality and may also pose risks to food safety. A novel method has been developed using acid preservation and flash dehydration to convert poultry and swine protein by-products into a protein meal that is about 15% more digestible than protein meals produced by conventional rendering methods. Depending on any new environmental regulations and animal by-product feeding laws, this technology will save North Carolina's poultry and swine industries more than \$5 million in mortality handling and disposal costs. More than 60 percent of poultry feed now includes supplemental enzymes to improve nutrient utilization, resulting in a 5 to 10% reduction in phosphorus emissions and improved enteric health.

NCARS #6390 Effect of Management on Turkey Production, Turkey Reproduction and Turkey Waste Handling

The poultry industry is faced with increasing local, state and federal legislation limiting the amount of nutrients applied to the land in the form of poultry manure, waste or litter. Recently, phosphorus (P) has received a great deal of attention as the rate-limiting nutrient. This research examined the effect of dietary P and phytase levels on the reproductive performance of turkey breeder hens. Decreasing dietary P resulted in no major reproductive problems for turkey hens. The immediate effects of lowering dietary P would be to decrease the breeder feed costs and poult costs, especially if the dietary P could be reduced without dietary phytase. Also, reducing fecal P would offer both immediate and long-term relief from manure and litter use restrictions. The poultry industry could improve its public image through environmental awareness.

**Subprogram Area 1c:
Biological Systems**

No integrated activities reported.

**Goal 1, Program Area 2:
Plant and Animal Germplasm, Genetic Resources and Conservation, and Plant Improvement**

**Subprogram Area 2a:
Crop Improvement**

NCARS #6137 Development, Evaluation, and Promotion of Underutilized and Novel Ornamental Plants

Several species of plants have been propagated and nursery grown at the J.C. Raulston Arboretum in preparation for distribution to evaluation sites within North Carolina. Ten sites have been verified as partners in this evaluation network, and personnel contacts have agreed to act as site stewards. The evaluation process will reveal which plants show potential for the warmest and coldest zones in North Carolina. This evaluation process and network will establish North Carolina as the premier state for nursery material evaluation and diversity for landscape sale and use.

NCARS #3647 Vaccinium and Rubus Breeding and Genetics

North Carolina blueberry and raspberry growers are dependent on the NC State University breeding program to develop cultivars adapted to the various regions of the state. The program has been successful in developing blueberry cultivars, and it is the leader in developing cultivars adapted to mechanical harvesting for both fresh and processing markets. Columbus rabbiteye blueberry was released. It is a mid-season ripening cultivar with excellent fruit size, fruit color, fruit quality and storage capability. In addition, three early to mid-season ripening cultivars that are adaptable to mechanical harvesting will be released in 2003. Developing raspberries adapted to warm, humid regions in North Carolina is critical to establishment of a stable raspberry industry in the state, and NC State University is the only institution that is systematically working toward this goal.

**Subprogram Area 2b:
Animal Improvement**

No integrated activities reported.

Goal 1, Program Area 3: Plant Protection Strategies (forest, horticultural and field crops)

NCARS #6305 Integrated Vegetation Management in Noncropland Environments

Weeds in aquatic and noncropland environments interfere with intended land uses, may pose threats to human health or safety and cost millions of dollars annually for management. Glyphosate applied in late summer or early fall to Japanese knotweed provides control for more than one season. Low rates (20 and 40 ppb) of fluridone applied in ponds in early spring provides good control of variable-leaf milfoil as long as no outflow of water occurred for several weeks after treatment. This project was the first to show that ornamental varieties of aquatic plants are very likely to become invasive if allowed to escape from water gardens into natural waters. Extension programs provided this and related information to pesticide applicators, county agents and Division of Water Resources staff. The information obtained in these studies aids state agencies in regulating ornamentals used in water gardens and has helped curtail the spread of giant salvinia, saving costs of controlling and eradicating these species.

NCARS #6417 Weed Management and Growth Regulators for Agronomic Crops

North Carolina growers are rapidly switching to herbicide-resistant cultivars. About 75% of the state's cotton and soybeans and 10% of corn are planted in resistant cultivars. A greater percentage of corn acreage should be in herbicide-resistant cultivars in 2003. Research and educational programs have focused on how best to manage weeds in these herbicide-resistant crops. This has included determining the need for residual herbicides, best timing of herbicide applications and value of mixtures and solutions for problem weeds not adequately controlled in the new systems. Extensive efforts have focused on comparing net returns of the new systems with conventional systems. Crop yields increased, input costs remained the same or dropped and quality problems such as foreign matter contamination were reduced. Estimated overall value to North Carolina cotton and soybean producers is \$48 million.

NCARS #6355 Introduced Pests of Honey Bees and Their Effects on Beekeeping and Crop Pollination

Research information provided through extension programs to pollination biologists, crop growers and beekeepers important theoretical and practical knowledge in the areas of beekeeping and crop production. Using pollen traps for the partial control of varroa mites is now considered to be a viable means of reducing varroa populations in managed honey bee colonies and when used with other IPM tools, provides another step towards the reduction of the beekeeping industry's dependence on chemical controls. Chemicals registered for control of bee mites are plagued with problems, including mite populations that are resistant to fluvalinate and coumaphos, the active ingredients of both currently registered chemicals for controlling varroa mites.

NCARS #6502 Management of Arthropod Pests of Turf and Peanut

Inadequate information may lead producers to apply too many pesticides to peanut and turfgrass crops. The peanut program produced management strategies, including a refinement of the Southern corn rootworm risk index for peanuts, which helps growers avoid preventive insecticide applications and effectively manage a challenging insect-vector disease (tomato spotted wilt virus). A speedier technique was developed for greenhouse screening of seedlings for evaluating rootworm resistance. The turfgrass research program produced immediate answers to pressing turfgrass insect problems (Oriental beetle, green June beetle, fire ants and mole crickets) and successfully transferred the technology to practitioners. Recently completed studies documented temperature and soil moisture effects on mole cricket ecology and allowed refinement of management strategies. Studies in Western North Carolina on a new turfgrass pest, the Oriental beetle, resulted in development of an initial forecast model.

NCARS #6504 Management of Arthropod Pests in Cotton and Grain Crops

In 2002, tests were planted into commercial cornfields at five sites in Eastern North Carolina. Tests included three neonicotinoid seed coatings (clothianidin, imidacloprid and thiamethoxam) at multiple rates against southern corn billbug and wireworm. The tests showed very high activity with the clothianidin and thiamethoxam. Rates of 0.25 mg/kernel and 1.25 mg/kernel were established for wireworms and billbugs, respectively. Grower and company tours and meetings were conducted to facilitate the development of marketed seed coatings at rates suitable for North Carolina conditions. These products will be cost effective, safer and more convenient for corn growers to use and will have an environmental benefit by reducing pesticide use by 92 to 98%. Wide-scale replacement of older pesticides is anticipated.

NCARS #0303 Biological Control of Arthropod Pests and Weeds

Studies examined the quality and efficacy of whitefly parasitoids from different sources, biological control as a management strategy for melon aphids, and evaluated the use of beneficial insect habitats on organic farms in the South. The research provided clear-cut evidence for growers on the value and economics of biological control for insect management in greenhouses. It also provided information for growers to select the best commercial products for these applications. The work with beneficial insect habitat will provide needed guidance on insect management for organic growers.

NCARS #6402 Management of Arthropods on Fruit and Vegetables in Western North Carolina

In recent years, vegetable growers in the piedmont and mountain regions of North Carolina as well as in surrounding states have experienced severe problems controlling the twospotted spider mite. Little is known about the cause of the problem, and there are few options for controlling mites on vegetables. A research and education program was conducted to identify the dispersal and movement of mites among crops during the season and to measure their susceptibility to various pesticides. Previous to this work, many growers preventively applied miticides to control mites regardless of their presence or abundance. Growers now have a knowledge base of the resistance status of mites to miticides, and they are able to control populations by avoiding the use of those chemicals to which mites have been identified as resistant.

NCARS #6503 Integrated Pest Management Strategies for Poultry and Livestock

Integrated management of pests important to livestock and poultry require a broad understanding of diverse management tools, including cultural, physical, biological and chemical control methods. Experiments have shown that covered fly traps containing an electrocution grid, through which cattle pass, reduce horn fly populations to threshold levels (200 per animal). Related work has focused on several species of dung beetles, some of which are capable of rendering dung pats unsuitable for horn fly oviposition and larval development. Further studies will examine the biology and benefits of dung beetles to horn fly management. Potentially, exploitation of these nonchemical control methods could lessen the chance of pesticide resistance in horn fly populations and reduce pesticide use.

NCARS #6169 Weed Management in Landscapes, Nurseries and Christmas Trees

Experiments have indicated that preemergence herbicide dissipation occurs more quickly than originally thought, and reapplication intervals of eight to 10 weeks may need to be shortened to maintain herbicide performance and reduce the need for hand weeding. Another option may be to apply lower rates of herbicide, but make applications more often. Such an approach requires that proper concentrations of herbicide are maintained. Proper selection and use rates of herbicides are important for effective weed control, and growers who rely on hand weeding will incur higher production costs.

NCARS #1001 Development of Plant Pathogens as Bioherbicides for Weed Control

Experiments demonstrated that *Pseudomonas syringae* pv. *Tagetis* (PST) plus organosilicate surfactant can control certain asteracea weeds, but levels of control were not sufficient. Further studies to improve efficacy of these treatments will be necessary before they can be recommended.

NCARS #6317 Small Fruit Diseases and Their Control

Since the early 1940s, USDA and NC State University plant pathologists have worked together with plant breeders to develop disease-resistant blueberry cultivars adapted to low-chill climates. The North Carolina blueberry industry thrives due to development of adapted cultivars. Some, such as Croatan, are so uniquely adapted that they are not widely grown outside North Carolina's coastal plain. Other disease resistant, low-chill cultivars like O'Neal have proven themselves adaptable to production areas around the world. Fungicide recommendations, cultural practices and discoveries of new diseases by NC State University plant pathologists continue to form the framework for blueberry disease management in the emerging blueberry industry in the Southeastern U.S. Through applied research and extension, resistance screening and fungicide trials help North Carolina growers solve the disease problems unique in this area.

NCARS #6364 Disease Management in Ornamental Crops

Characterization of Phytophthora diseases in the floriculture industry will provide growers with guidelines for managing production practices and selection of the most appropriate disease management tactics. In Fraser fir plantations with Phytophthora root rot, understanding dispersal and pattern of disease development will help growers select the best disease management tactics including site, fir species, and fungicide usage for production. Adoption of biopesticide use by greenhouse growers will reduce the impact of conventional fungicides in the environment, improve worker safety and conserve beneficial microbes.

NCARS #6396 Ecological and Population Based Management of Fungal Plant Pathogens

Yield losses associated with Rhizoctonia disease of potato and Sclerotinia blight of peanut can vary from 20 to 40%. Successful management of Rhizoctonia and Sclerotinia diseases will require a better understanding of how introduced pathogens interact with indigenous pathogens of the same species to reduce yield loss, contribute to increased crop production, reduce fungicide use, minimize environmental impact and increase profits.

NCARS #6536 Nematode Interactions With Resistant and Susceptible Plant Genotypes

Plant-parasitic nematodes cause estimated losses to corn, cotton and soybeans of over \$37 million annually. Research has developed and evaluated nematode management tactics, and extension programs have provided education and information to growers, extension agents, consultants and other professionals who work with growers. Recommended strategies include

crop rotation, variety selection, wheat/soybean double-cropping and the application of organic materials to soil. More than 50% of the soybean and corn acreage is grown in a planned rotation that aids in prevention of disease losses. Most of the 600,000 acres of small grain in the state is double-cropped with soybean. This practice minimizes soybean yield loss due to soybean cyst nematode that infests 60% plus of the state's acreage of soybeans. Soybean yield typically averaged 24 bu/acre through the 1990s, and in 2000-2001, soybean yields averaged over 30 bu/acre. This increase can be attributed to improved varieties and improvement in disease management strategies used by soybean growers.

NCARS #6327 Weed Management Techniques for Small Fruits and Vegetables

Weeds continue to be one of the worst pests in vegetable crops. Pigweed, a common weed in fields of sweet potatoes and many other crops, is difficult to control, and growers usually mow the weed when it emerges over the crop canopy. Studies on a research station and a grower's field determined that mowing for pigweed (or Palmer amaranth) should take place between 20 and 40 days to prevent reduction of yield and quality of sweet potato roots. More than half of growers are expected to adopt this practice.

NCARS #6160 Integrated Peach Disease Management and Evolutionary Dynamics and Competitiveness of Bacterial Plant Pathogens

In late summer 1999, plum pox virus was discovered in the peach-growing area of Pennsylvania, the first report of this devastating disease in North America. Because the virus is readily transmitted in propagative plant material, the issue raised was how wide spread was the disease and could it be eradicated? As a part of a coordinated regional project (NE501), during 2000 and 2001, more than 90% of the peach orchards in North Carolina were surveyed, and all were found to be negative for the virus. Re-surveys done in 2002 were also negative. As of the end of 2002, plum pox had been detected only in Pennsylvania and in areas of Eastern Canada. If this disease had been allowed to spread from the initial sites, at minimum, it would have cost the stone-fruit industry millions of dollars.

NCARS #6223 Apple Disease Management

The Southern Appalachian Integrated Apple Orchard Management Research and Implementation Project continued to make progress in reducing the number of fungicides classified as B2 carcinogens and has set a standard for the use of the reduced risk disease management program in orchards throughout the Southeast. Continued research on currently registered QoI (strobilurin) fungicides and experimental ones has demonstrated their value in the summer disease control program in the Southeast. As a part of the reduced risk management program, growers were asked to not use dithiocarbamate fungicides after the pre-bloom period, not to use any benzimidazole fungicides and to use strobilurin fungicides in the last one to three cover sprays. Most growers followed these recommendations; 85.7% of growers used strobilurin fungicides in the late season sprays, thereby providing at least a 42-day interval between the last captan application and harvest.

**Goal 1, Program Area 4:
Animal Diseases and Animal Health**

No integrated activities reported.

**Goal 1, Program Area 5:
Farm Business Management, Economics and Marketing**

NCARS #6510 Price Risk Management Strategies in Food and Grain Marketing

Research has focused on 1) grain marketing strategies that can enhance the safety net in the new Farm Bill, 2) potential impacts of repeal of the Jones Act on NC and US soybean market, and 3) factors impacting trade in the soybean complex. The research on marketing strategies combined with effective program outreach is providing producers with information to make more informed and beneficial marketing decisions and risk management decisions. The work on trade in the soybean complex is helping growers, organizations and policy makers to be more informed on these factors and policies, and their influences on the market.

NCARS #6527 Risk Aversion, Risk Shifting and Alternative Payment Mechanism in Settlement of Broiler Contracts

Research has examined issues associated with grower complaints about payment mechanisms used by poultry integrators to settle broiler contracts. The work has provided information that shows the potential danger of uniform regulation of production contracts. One type of contract may be preferred by growers with relatively lower risk aversion, whereas some other payment mechanisms may be preferred by more risk-averse growers. The best outcome is obtained in situation where there is competition for growers and where different integrators offer different contracts such that growers can self-select themselves into contracts that are best suited to their types.

NCARS #6472 Economics of Modern Marketing Systems and Environmentally Sound Pork Production in North Carolina

Most research and extension activities have focused on economic analyses of various methods of altering swine production systems to reduce expected or potential negative environmental effects. Work completed in the project has had an impact through direct participation of the PI in development of the new EPA CAFO rule and evaluation of proposed alternative manure management systems for North Carolina swine farms. Work completed in this project contributes to the theoretical, conceptual, and empirical basis for future development and economic evaluations of livestock production systems and policy to achieve societal objectives, including enhanced environmental quality. Information gained from this work is provided to policy-makers, extension educators, partners and farmer cooperators.

**Goal 1, Program Area 6:
Product Development**

NCARS #6616 Functional Fish Food Ingredients Produced by Solubilization/Reprecipitation

Alkaline solubilization/reprecipitation was studied to optimize process parameters for protein recovery from Atlantic croaker flesh. The alkali-aided process appears to give higher protein yield (20 %) and better functional (gelling) properties from Atlantic croaker than does the conventional washing process for surimi manufacture. Since that fishery is more limited in supply of fish than traditional surimi fisheries, an alkali-aided approach to surimi manufacture could enable development of an economically viable market for surimi from this species.

**National Goal 2:
A Safe and Secure Food and Fiber System**

**Goal 2, Program Area 7
Food and Fiber Processing, Safety and Quality**

NCARS #1006 Insect and Manure Management in Poultry Systems: Elements Relative to Food Safety and Nuisance Issues

This series of investigations is to examine potential roles of the house fly and other arthropods associated with poultry production in the transmission of foodborne pathogens. The association and interaction of bacteria and their vectors may encourage the re-evaluation of existing pest management practices, which would be communicated to growers and companies through educational programs.

NCARS #0292 The Poultry Food System: A Farm to Table Model

Findings indicate that both the contact surface and level of organic matter can influence the survival and persistence of *C. jejuni* and *Salmonella* species on food contact surfaces, including persistence for significant lengths of time, which may lead to an increased risk of cross-contamination between food handlers, ready-to-eat foods and other food contact surfaces. The data indicate the dangers inherent in poor food handling practices, and support our need to increase educational efforts aimed at reducing cross-contamination in home and retail kitchens. Other work demonstrated the usefulness of HabaGUARD conveyor belts in preventing or reducing the potential risk of bacterial cross-contamination in poultry processing plants. These new food safety technologies should translate to less contaminated product reaching the marketplace and fewer foodborne disease outbreaks.

**National Goal 3:
A Healthy, Well-Nourished Population**

**Goal 3, Program Area 8:
Human Nutrition and Human Health**

NCARS #6479 Biology and Control of Nuisance Vector Arthropods in North Carolina

La Crosse encephalitis (LACE) is a pediatric illness caused by a mosquito-transmitted virus. The disease is endemic in Western North Carolina with cases being reported each year for the past 25 years. In 2002, a record high of 21 cases were reported to the state health department. A retrospective sero-epidemiological study was conducted to determine the frequency of exposure of people residing in Western North Carolina to La Crosse virus. These results indicate that transmission of La Crosse virus is widespread throughout Western North Carolina. Recently, a socio-economic study of La Crosse encephalitis was completed. Disease case patients were interviewed to assess the economic and social impacts of the illness. The total direct and indirect medical costs associated with La Crosse encephalitis for 25 case patients with frank encephalitis were estimated to be \$794,303. On average, the direct and indirect medical costs of a single case of LACE were \$32,974 (\pm SD = \$34,793, n = 25). For the 25 LACE patients, 55.19 (54.83%) of 100.59 life years were impaired to some degree. Along with impaired life years, approximately 13.00 Disability Adjusted Life Years (DALYs) were accumulated for the 25 case patients over 100.59 life years of study. The socioeconomic burden resulting from LACE is substantial, which

highlights the importance of the illness in disease endemic areas of North Carolina, as well as the need for active surveillance and prevention programs for the vector/virus complex.

National Goal 4: An Agricultural System that Protects Natural Resources and the Environment

Goal 4, Program Area 9: Soil, Water and Air Quality Conservation and Management

NCARS #6571 Reducing the Environmental Impact of Swine Production Through Nutritional Means

A series of applied research activities, coupled with industry outreach, are providing the swine and poultry industries with strategies to reduce the impact of production practices on the environment. Swine housing equipped with belts to harvest manure have 75% lower ammonia emission, lower odor and waste streams that are more flexible in their use, including capture of energy, ash as a feedstuff, and reduction in ammonia and odor emission. Infrared technology to test the quality of hatching eggs, feedstuffs and complete feeds has the potential to allow hatcheries to only set high quality eggs, to reduce pig feed costs up to 2% per unit of gain, and to reduce nitrogen waste by 5 to 10 %. Other work has developed a method to capture and convert ammonia in swine urine into ammonium sulfate, thus reducing ammonia emission and capturing a commercial-grade fertilizer material. Information from this work is provided to the swine industry through the Animal and Poultry Waste Management Center and other educational vehicles.

NCARS #6568 Development of Tools for Assessing Environmental Impact and Remediation of Agricultural and Development Activities on a Watershed Scale

Efforts were focused on building tools to simplify and enhance the input and output sides of both large-scale and small-scale watershed hydrology and water quality models. The ability to apply complex models that require a significant amount of spatially descriptive data is generally not within the grasp of small town or county level planners. By teaming with USEPA and local government associations, a group of mid-western and southeastern universities hope to provide those capabilities through web browser-based access tools. There should be an immediate, positive impact for these governmental units as a result of using better data to make critical planning and siting decisions. Their decision making ability is enhanced through use of the tools and with training and education provided through extension programs.

NCARS #6457 Effects of Land Use and Management Practices on Hydrology and Water Quality on Poorly Drained Watersheds

Excess pollution in Eastern North Carolina has led to unprecedented regulations to reduce the nitrogen loading to the Neuse River by 30%. The primary culprit is nonpoint sources, and agriculture is a potential source. Reduction can be achieved by intercepting the polluted water before it reaches groundwater and denitrifying the nitrate to nitrogen gas. Redox potential is one indicator of denitrifying conditions. Buffer width, presence and type of vegetation, and buffer location relative to the stream are factors that influence denitrifying activity and nitrate-nitrogen concentrations. Understanding and use of these principles can help landowners make more informed decisions regarding practices that can be used to reduce nitrogen loading.

NCARS #6575 Engineered Processes to Enhance Nutrient Management and Reduce Environmental Impacts of Animal Manure

Intensive livestock production presents challenges for preventing air and water quality degradation. Concerns include odor, ammonia emission, and nutrient management. This work has focused on demonstrating and evaluating alternative systems in pilot-scale and full-scale before they are recommended for farmers. System performance evaluation, demonstration and field days are used to inform growers, regulators and the industry about these systems.

NCARS #1000 Animal Manure and Waste Utilization, Treatment and Nuisance Avoidance for a Sustainable Agriculture

Alternative swine manure management systems that address odor, ammonia emission, nutrient management, economic efficacy and water quality are being demonstrated and evaluated. Demonstrations, field days and other vehicles are used to communicate findings to industry, growers and regulators. Livestock producers need more management options to address these environmental concerns, but management options must be reasonable in cost and management requirements, and they must show clear environmental benefits. These evaluations should have application on swine farms in North Carolina as well as other swine producing states.

NCARS #6224 Environmentally compatible nursery crop production practices

Nursery and floriculture crops have been the fastest growing agricultural sector in North Carolina over the last decade, with annual sales increasing by approximately \$24 million per year. The wholesale value of these crops is about \$1 billion annually. To establish successful businesses, new growers need a thorough understanding of how to grow and market perennial crops. Workshops, short courses, comprehensive manuals and Web sites for growers and extension agents convey a range of

information, including nursery statistics, regulations, licensing and certification, labor laws, vendors, site and crop selection and the latest research results.

NCARS # 6454 Analyses of Technologies for Odor Control and Converting Wastes Into Value-Added Products

Eighteen potential alternative technologies to lagoon/spray field technology now used to treat waste on most North Carolina swine farms, and most have been installed and are being evaluated for performance and economic applicability. Livestock producers, agribusiness, government and environmental interest groups are provided objective, science-based information that can be used to influence decisions regarding the planning and implementation of new animal waste management technologies in North Carolina and elsewhere.

NCARS #6652 Precision Agriculture for Agronomic Crops and Nitrogen Management for Corn in Eastern North Carolina

Optimizing fertilizer management improves farm profitability and reduces the likelihood of nitrogen (N), phosphorus and sediment runoffs from fields to the Albemarle-Pamlico estuarine system's waters. In the Tidewater region, fertilizer N is applied to about 29% of the state's corn, 26% of wheat, 13% of cotton and 95% of Irish potato acreage. Scientists and producers developed fertilizer rate and timing recommendations and strategies for precision management, water control and reduced tillage to optimize returns and reduce runoff. Estimated impacts: If 50% of this area adopted best management practices resulting in a 50% reduction in N runoff on the treated fields, then total N runoff would be reduced by about 25%. A 10% fertilizer N use reduction would save farmers about 6.6 million pounds of N or \$1.3 million per year, a substantial N reduction in the region nearest to the Albemarle-Pamlico estuarine system.

NCARS #6647 Evaluation of Soil and Site Criteria for On-Site Wastewater and Land Use Decisions

On-site wastewater systems account for 50% of the wastewater treatment systems in the state. Various educational programs, demonstrations, field days and workshops for homeowners, installers and septic haulers demonstrate proper maintenance and management of systems. If properly selected, sited and managed systems are used, the individual may save the cost of repairing or replacing a failing system. Approximately \$70 million is spent annually on repairing failed systems; proper maintenance and management could reduce that cost by 50%.

NCARS #6295 Aluminum Toxicity and CA Deficiency Constraints to Root Growth in Acid Soils

Under Neuse River Rules, the agricultural community was expected to reduce N loading by 30%. This program developed a nitrogen loss estimation worksheet tool, educational programs, training, demonstrations and other outreach activities to help the agricultural community meet the N reduction goal. Without the development of this tool and associated outreach activities, producers in the Neuse Basin would be forced to use the prescribed BMPs on all acres. A cost/benefit analysis of the mandated BMPs demonstrated that most of the BMPs will cost producers money. Therefore, by being a part of the local area N reduction plan, most producers will save money and still meet the goals of the Neuse Rules.

NCARS #6558 Nutrient Management Programs for Mountain Area Crops

Excessive height growth is a tomato seedling problem in the tobacco-float system, an adapted seeding method that lowers production cost, eliminates irrigation systems and management and increases fertilizer efficiency. Efficient tomato transplant production using such technology could lower costs and fill empty tobacco seedling greenhouses. While drastic height-control measures may damage post-transplant fruit yield and quality, experiments from 1998 to 2000 and field tests in 2001 and 2002 indicated that several tested height-control measures can be used without damage to yield, fruit earliness or quality.

**Goal 4, Program Area 10:
Forest, Pasture, Wildlife and Fish Resource Conservation Management**

NCARS #6387 Aquaculture of Southern Flounder and Improved Water Quality Management of Ponds in Eastern NC

Research and outreach activities have focused on further defining the nutritional requirements of southern flounder, identifying the environmental causes of sex determination in juvenile flounder, and evaluating the production characteristics of hybrid striped bass grown in ponds with zero discharge. Information on the optimum temperature for sex determination of flounder has a direct impact on management practices and design parameters for southern flounder producers. This information is critical to the economic success of flounder farming. Adoption of the zero discharge method of hybrid striped bass production will reduce water usage and effluent volumes by more than 70% - saving pumping costs and well water usage. Zero discharge production of hybrid striped bass represents a significant step toward minimizing the environmental impact of hybrid striped bass culture.

NCARS #3975 Improved Efficiency of Water Reuse Aquaculture Systems Through Advancements in Treatment Technologies.

Since 1989, North Carolina State University researchers have been working to develop technology for intensive fish production indoors in areas of the state with limited water supplies. The North Carolina Fish Barn program combines worldwide water treatment technologies in the production of freshwater and marine fin-fish with very little water usage.

Once unique within the United States, it is now emulated at other land-grant universities. This College of Agriculture and Life Sciences program provides design and development services to the agribusiness community. The Fish Barn program assisted Southern Farm Tilapia in developing two operations with a production capacity of 750,000 pounds per year. The Fish Barn program also assisted Deca J Farms in developing a yellow perch facility that will have the capacity to produce more than 1 million fish per year when completed in 2004. The Fish Barn program also provides technical assistance to seven other tilapia production fish barns in North Carolina that will have the capacity to produce nearly 1.5 million pounds of fresh fish annually.

NCARS #6153 Mountain Aquaculture Research

The safety of foods, particularly seafood and meats, is under ever increasing scrutiny from agencies, the public and the media. Even the limited use of approved antibiotics and other therapeutics in open water fish systems is viewed negatively by environmental advocates and some consumers. However, options for effective and economical prevention and treatment of disease on fish farms are very limited. The use of vaccines in the production of freshwater trout offers an alternative to antibiotic use. On trout farms in North Carolina, the use of antibiotic-containing feeds has been reduced from 8.8% in 1996 to 1.5% in 2002 as a result of the application of injection vaccination against ERM. Concurrently, the percentage of total trout lost attributed to disease has dropped from 63% to 30% in NC while remaining at 74.3% nationally. Increasing effective use of vaccines against other important trout diseases will help further reduce the cost and impact of disease to trout producers.

**National Goal 5:
Enhanced Economic Opportunity and Quality of Life for Americans**

**Goal 5, Program Area 11:
Individual, Family and Community Economic Development and Quality of Life**

NCARS #1962 Rural Economic Development Alternatives in the New Competitive Environment

Since the 1970s, the population of rural areas in North Carolina and many other states has grown steadily; between 1990 and 1999 alone, 250,000 people moved to North Carolina's rural counties. This research on the determinants of rural-urban population dynamics indicates that the primary driver of these trends is a widening of the geographic extent of urban labor markets (as opposed to reinvigoration of the economies of rural areas). This information has assisted planners and policy makers in North Carolina's rural counties in formulating economic development strategies. Economic development policies at the municipal, county, and state levels are overwhelmingly oriented around stimulating employment growth. Research on the allocation of employment growth represents an important input into current debates over desirable economic development strategies, land use planning, and smart growth. Because of this, this work is eliciting significant interest on the part of policy makers and local government officials throughout North Carolina. Industrial recruitment is usually viewed as a key element in replacing jobs in declining rural industries that formerly were filled by county residents. This research suggests that less than half of new jobs actually go to those residents. This is particularly applicable to rural communities located near fast growing urban counties.

NCARS #6532 The Public Economics of Fast Growing Regions

A model was developed and calibrated to estimate the impacts of state and local fiscal policies on the rate of economic growth in counties. The model was estimated using data for North Carolina over the period 1980-95. The model allows the estimation of changes in combinations of tax rates and public spending on local economic growth. A measure of shortages in public infrastructure was developed from data on temporary public school facilities. Data were collected for two years from all public school districts in North Carolina to implement the measure. State and local public policymakers are better able to estimate the impact of combinations of specific tax rate and public spending combinations on local economic growth in North Carolina. Information is shared with policy makers, government agencies and the public.

NCARS #6465 Implications of Technological and Social Changes for the Food System

This project focuses on some of the main technological and social changes that are underway across the modern food and agricultural system. Work included surveys related to consumer acceptance of biotechnology and public attitudes about agriculture. Work is underway related to the practices that leading companies use to develop and market new food products. Research has also focused on the international dimensions of consumer perceptions of biotechnology as well as the views of world opinion leaders, food industry leaders, and global government leaders about agricultural biotechnology. The benefits of biotechnology will only be realized if society accepts the products as safe and ethical. This research provides guidance as to how to better integrate biotechnology into society.

NCARS #0185 Commodities, Consumers and Communities: Local Food Systems in a globalizing Environment

Parameters were developed to analyze local food commodity production by applying import substitution theory to initiatives for more localized food systems. This project was based on the contention that while food systems that are more concentrated at the local scale can build some level of resistance to market hegemonies, they must be monitored to examine whether they may simply replicate inequitable and unsustainable patterns of labor and the use of land and resources on a local community scale. In North Carolina, the focus was on peanuts, one of the most important cash crops in the depressed Northeastern portion of North Carolina. The difference between success and failure for many small and large farmers will be in making the transition to a lower cost production system. Because of pressures on pesticide use and high costs of crop protection on peanuts, IPM practices will become increasingly important to those that do continue to produce peanuts. Available evidence suggests that the results from these studies have been received by producers, the industry, community and policy makers and are being used to improve resource allocation and inform decision-making at various levels, in the process of contributing to a more sustainable agricultural sector.